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AUTOMATED CALCULATION OF PROTECTION FACTORS FOR THE SODIUM CHLORIDE RESPIRATOR QUANTITATIVE FIT TEST INSTRUMENT

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USAF SCHOOL OF AEROSPACE MEDICINE
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NOTICES

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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An automated procedure for calculating a respirator protection factor is presented in this report. This procedure not only reduces the sodium chloride leak test data, but also calculates a protection factor using a voltage-to-frequency converter circuit to do time-averaged integration and a least-squares curve fit computer program.

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PREFACE

The author is grateful to the people at the USAF School of Aerospace Medicine, Brooks AFB, Tex., who contributed suggestions and criticisms during the development of this report. Special thanks are due to Richard L. Miller, Ph.D., Lt Col Robert W. Krutz, and Mr. Clarence F. Theis of the Crew Environments Branch.

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INTRODUCTION

The purpose of this report is to present an automated procedure for calculating a respirator's protection factor (PF) afforded to the respiratory tract and eyes against chemical warfare (CW) agents in particulate, aerosol, or vapor form. The participating nations of the Air Standardization Coordinating Committee (ASCC) have drafted a North Atlantic Treaty Organization (NATO) Standardization Agreement (STANAG) recommending a sodium chloride quantitative fit test scheme for this procedure [1]. The Chemical Defense Establishment (CDE) in the Ministry of Defense (MOD) of the United Kingdom is credited with developing the basic sodium chloride (NaCl) quantitative fit test technology [2-11]. The United States Air Force School of Aerospace Medicine (USAFSAM), which has had several years of laboratory experience with the sodium chloride quantitative fit test instrumentation [1], has reviewed and endorsed this draft agreement.

Our experience with the sodium chloride quantitative fit test instrumentation has shown one area to be of particular concern; namely, the method of reducing the collected data (respirator sodium chloride penetration concentration for a particular exercise protocol) and calculating a protection factor. The STANAG agreement draft proposes that:

> "When the output of the flame photometer fluctuates during a measurement of penetration, the maximum output is to be used to calculate the Protection Factor. For this purpose, occasional transient increases in output the duration of each of which does not exceed 2 sec may be ignored." [1]

In addition, various interested organizations have developed and reported on the following data reduction schemes for respirator quantitative fit testing [2,13-43]:

a. selection of the overall maximum output peak

b. arithmetic average of the maximum output peaks

c. arithmetic average of the maximum output peaks and minimum valleys (midpoint)

d. visual estimation of the midpoint between the maximum output peaks and minimum valleys

e. time-averaged or integrated value.

This report develops, with some rigor, an automated procedure to reduce the NaCl leak test data and calculate a protection factor. An overview of the USAFSAM sodium chloride respirator quantitative fit test instrument is followed by: a discussion on conventional protection factor calculations; the use of a voltage-to-frequency (V/F) converter circuit to do time-averaged integration; and, finally, a least-squares curve fit computer program to calculate a protection factor.

USAFSAM SODIUM CHLORIDE RESPIRATOR QUANTITATIVE FIT TEST INSTRUMENT

The CDE sodium chloride respirator quantitative fit test method, described in British Standards 4400 and 2091, has been adapted and modified by USAFSAM to measure the protection factor in the respiratory and eye compartments of aircrew chemical defense respirators [3,11]. This instrument generates a solid aerosol of sodium chloride crystals as the challenge atmosphere. The concentration of the challenge atmosphere in an aircrew respirator is measured using a hydrogen flame photometer, and the result is displayed on a strip-chart recorder. This technique allows protection factors as high as 10^6 to be calculated.

Instrument Description

Illustrated in Figure 1 are the primary components used in the USAFSAM sodium chloride respirator quantitative fit test instrument [1,3,11,33]. The sodium chloride solid aerosol challenge atmosphere is generated by atomizing a sodium chloride solution, drying the liquid aerosol in a drying tube, and delivering the dry cloud to the top of a transparent plastic hood. A subject, having donned a respirator, enters the hood and performs a series of breathing and head movement exercises. A sampling pump is used to draw a portion of the atmosphere from the interior compartment of the respirator. This sample is vaporized in a hydrogen flame photometer, and the output signal is displayed on a strip-chart recorder.

Production of the Sodium Chloride Challenge Atmosphere

The challenge atmosphere is generated by atomizing a 5% aqueous sodium chloride solution, prepared by dissolving 50.00 grams of sodium chloride in 1000 ml of distilled water. Operating a Dautrebande atomizer at 70 psi (482.3 kPa) (clean dry compressed air) yields a flow through the atomizer of 35 liters/min (STP). The liquid aerosol from the atomizer is then injected perpendicularly into the air stream flowing through a mixing and drying tube. The 50 liter/min (STP) source of clean dry air evaporates the water from the liquid sodium chloride aerosol and produces a solid sodium chloride aerosol challenge atmosphere. The mass median aerodynamic diameter (MMAD) of the dry sodium chloride crystals range from 0.4 - 0.6 μm. The sodium chloride challenge atmosphere is delivered through a short length of Tygon tubing to the top center of a transparent plastic hood that covers the subject from head to waist. The hood's vertical displacement is controlled by releasing a locking pin and turning a cable-connected crank. The diameter of the hood permits a subject to move freely his arms, shoulders, and head. An adjustable cloth collar attached to the bottom edge of the hood is drawn snugly around the subject's waist and serves to contain the challenge atmosphere [1,3,11,33].

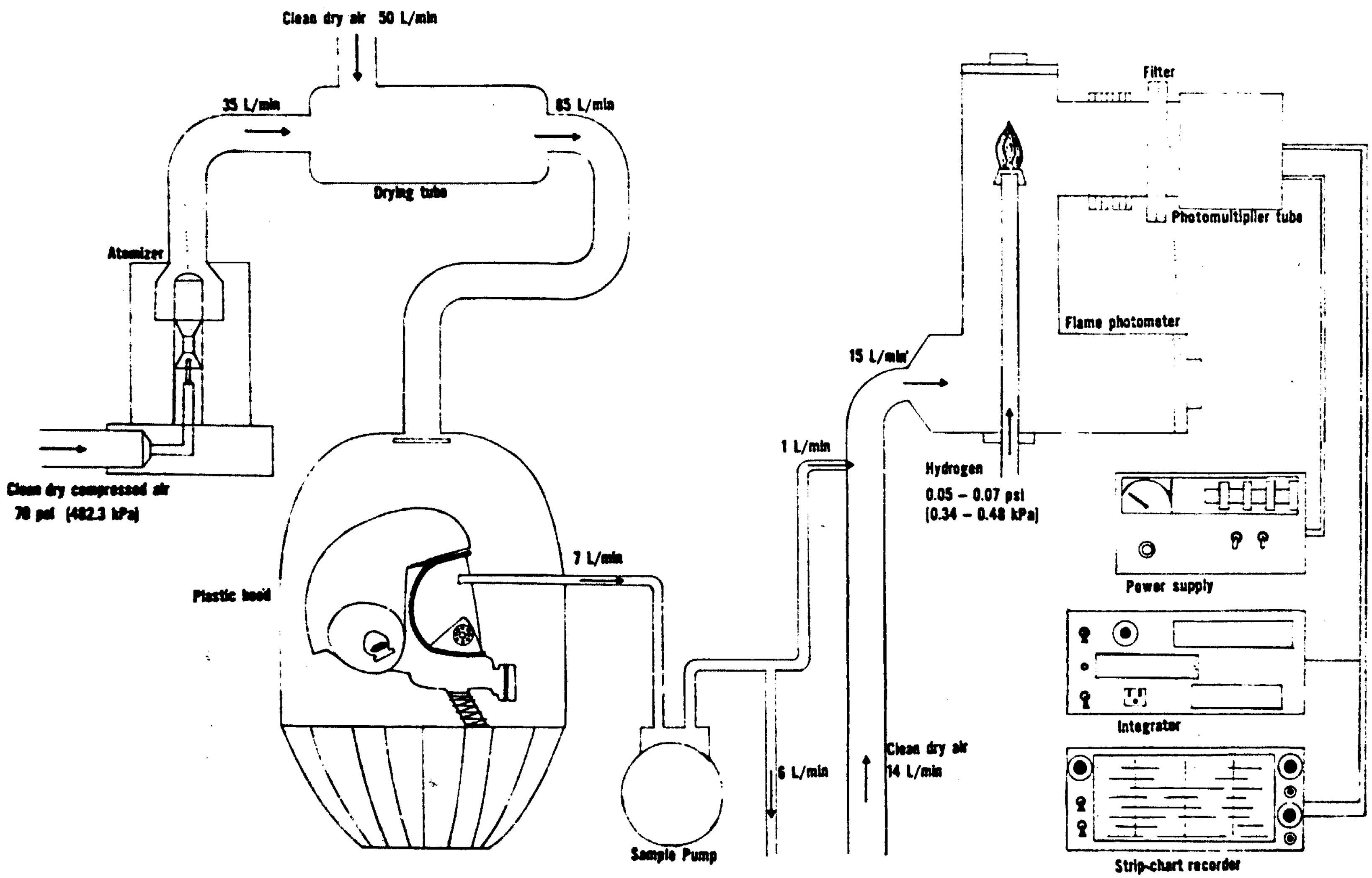

Figure 1. USAFSAM sodium chloride respirator quantitative fit test instrument.

Measurement of the Sodium Chloride Respirator Leakage

When evaluating a full-face aircrew chemical defense respirator, a primary concern is the penetration of the sodium chloride challenge atmosphere into the visual compartment. In order to make this measurement, an aluminum tube, approximately 1 in. (2.54 cm) long and 0.25 in. (0.635 cm) i.d., is so fitted through and sealed to the protective device's visor that the distance from the cornea to the open end of the aluminum sampling tube (interior to the respirator's visor) is not greater than 0.8 in. (2 cm) [1].

The concentration of the sodium chloride challenge atmosphere that has leaked into the visual compartment is determined by continuously sampling gas from this site and vaporizing it in the flame photometer. Sampling is accomplished by attaching one end of a short length of Tygon tubing to the open end of the aluminum sampling tube (exterior to the respirator's visor), and then passing the opposite end of the plastic tubing through a sealed port in the top of the hood. A pump--of the metal bellows positive displacement, continuously sampling type--is connected to the open end of the hood's port, and is used to draw a gas sample from the respirator's visual compartment (constant 7-liter/min flow). Before the 7-liter/min sample is injected into the hydrogen flame photometer, a 6-liter/min amount is bled to the ambient atmosphere through a calibrated orifice. The resulting 1-liter/min sample is diluted with a 14-liter/min flow of clean dry compressed air, and this mixture is then injected into the photometer for analysis. The determination of the 7-liter/min mask sampling rate, 6-liter/min bleed-off, and subsequent 14-liter/min dilution of the 1-liter/min portion of the penetration sample was based on two experimental observations: First, the 7-liter/min sampling rate was selected to minimize the negative pressure within the respirator's visual compartment; i.e., a greater sampling rate was observed to distort the penetration measurement. Second, the sodium chloride-air mixture composition was metered to yield optimum performance of the hydrogen flame photometer for PF's ranging from 10^4 to 10^6 [33].

The flame photometer used to analyze the sampled sodium chloride aerosol from the interior of a respirator consisted of two primary components: a burner to vaporize the sodium chloride crystals, and an electronic package to quantify the actual leakage concentration.

Hydrogen is used as the combustion gas for the burner because of its pure, almost colorless (pale blue) flame. With the particular gas jet being used, the hydrogen source is regulated to flow at a nominal 0.05 - 0.07 psi (0.34 - 0.48 kPa); these conditions produce a 1-in. (2.54 cm) vertical flame [33].

The electro-optic scheme used to quantify a respirator's sodium chloride leakage is shown in Figure 2 [33]. In operation, the sampled sodium chloride crystals are vaporized in the hydrogen flame photometer. The 589 nanometer (nm) wavelength optical bandpass filter is used to detect the yellow sodium emission lines and to reject all other undesirable light energy emissions. Detection and quantification of the intensity of the filtered yellow light is accomplished with a photomultiplier tube (PMT). In principle, the PMT output current is directly proportional to the intensity of the yellow light impinging upon its cathode. Thus, since the intensity of yellow light produced by the hydrogen flame is proportional to the concentration of sodium chloride in the medium surrounding the flame, the PMT output current is also proportional to the sodium chloride concentration around the flame.

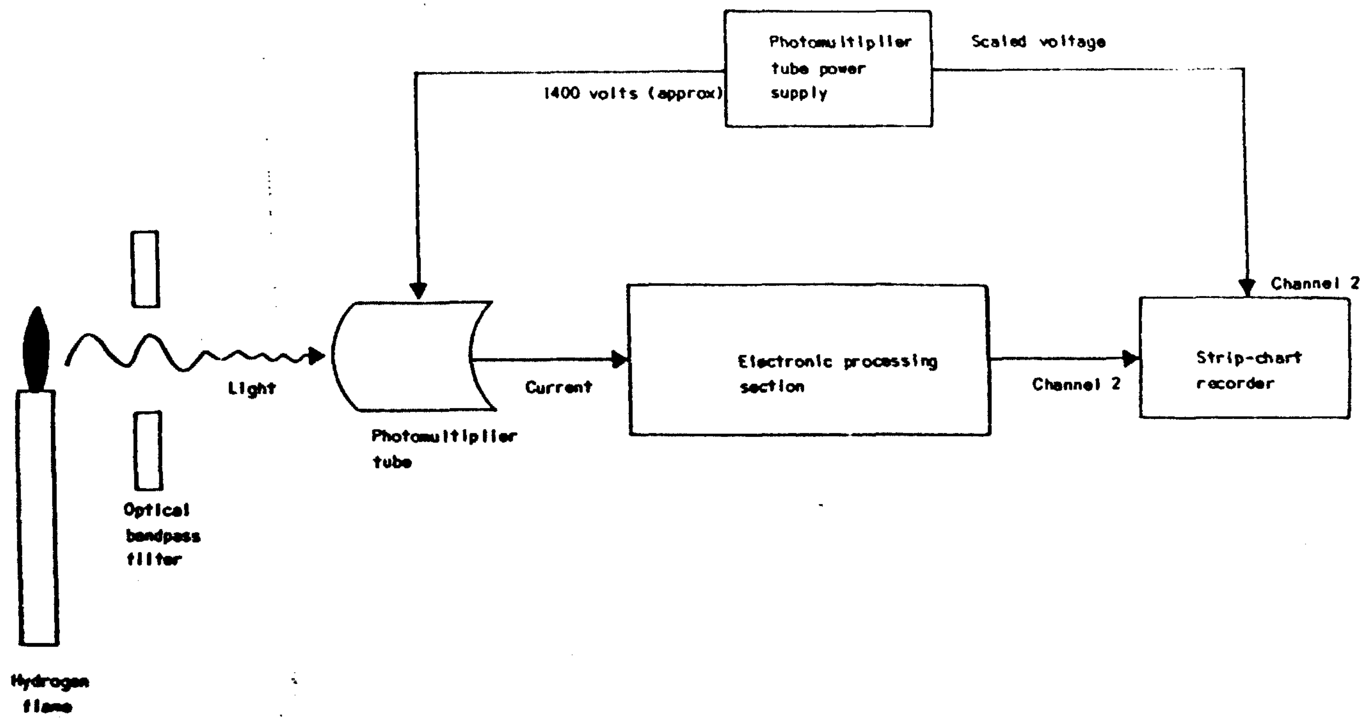

Figure 2. The electro-optic processing scheme used to quantify a respirator's sodium chloride leakage.

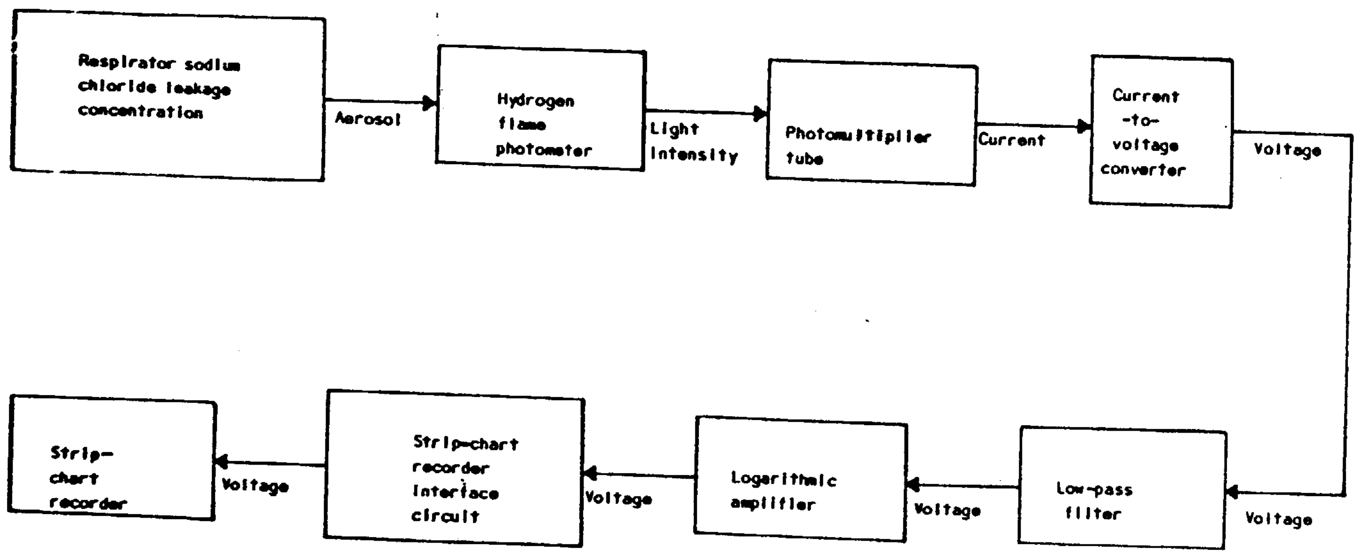

Figure 3. The electronic processing scheme used in the USAFSAM sodium chloride respirator quantitative fit test.

Electronic processing of the PMT output current is necessary for three reasons:

a. The PMT output current must be converted to a voltage of sufficient magnitude so that the leakage can be displayed on a strip-chart recorder.

b. The PMT output current must be filtered to reduce the random high-frequency noise components.

c. The PMT output current must be scaled logarithmically to accommodate a wide dynamic range (four orders of current magnitude) on a single span strip-chart recorder.

The electronic processing scheme used in the USAFSAM sodium chloride respirator quantitative fit test instrument is shown in Figure 3 [33]. A Harris Semiconductor Corporation (HA2-2905-5) integrated circuit is used as the active element in the current-to-voltage converter; an Analog Devices Corporation (Model 755N) integrated circuit is used as the logarithmic amplifier; and a Signetics Corporation general purpose 741 operational amplifier integrated circuit is used in the interface circuit to drive the strip-chart recorder. The low-pass filter and logarithmic amplifier are shown in Figure 4 [33]. Illustrated in Figure 5 are the electronics associated with the strip-chart recorder interface circuit [33]. The PMT detector is an International Telephone and Telegraph (ITT) special purpose 16-stage, electrostatically focused, model FW130 tube. With an operating anode-to-cathode potential of 1300-2200 volts, the PMT's dark current is 100 times less than the PMT background current (PMT background current is defined to be that current produced by the tube when the hydrogen flame is surrounded by a medium free of sodium chloride). With the associated electronics package (Figs. 4 and 5), the following transfer function relates the PMT output current to the strip-chart recorder voltage:

$$v = 2 + \log_{10} \left\{\frac{i}{1.1\ \mu A}\right\} \tag{1}$$

where

v = output voltage to strip-chart recorder (in volts), and

i = PMT output current (in microamperes)

In addition, this transfer function is illustrated graphically in Figure 6 [33]. Of particular attention is the fact that the PMT output current spans 11 nanoamperes (nA) to 110 microamperes (μA), and the associated strip-chart recorder voltage spans 0 to 4 volts; i.e., a 1-volt output change occurs per decade of input current change.

In order to calculate the protection factor for a subject's chemical defense respirator, the foregoing information concerning the dynamics of the instrument must be coupled with one more factor--the calibration procedure.

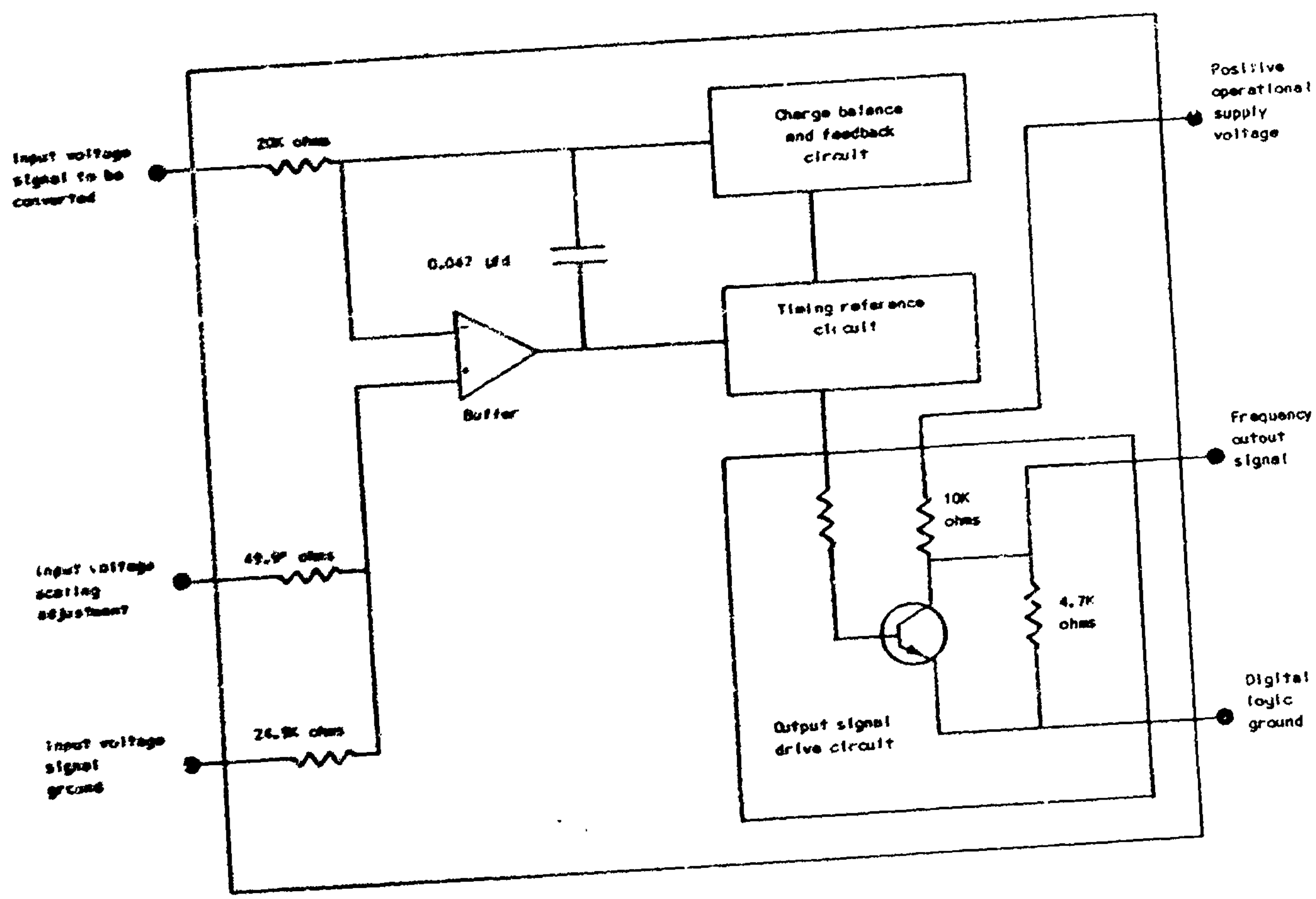

Figure 4. Current-to-voltage converter, low-pass filter, and logarithmic amplifier circuits.

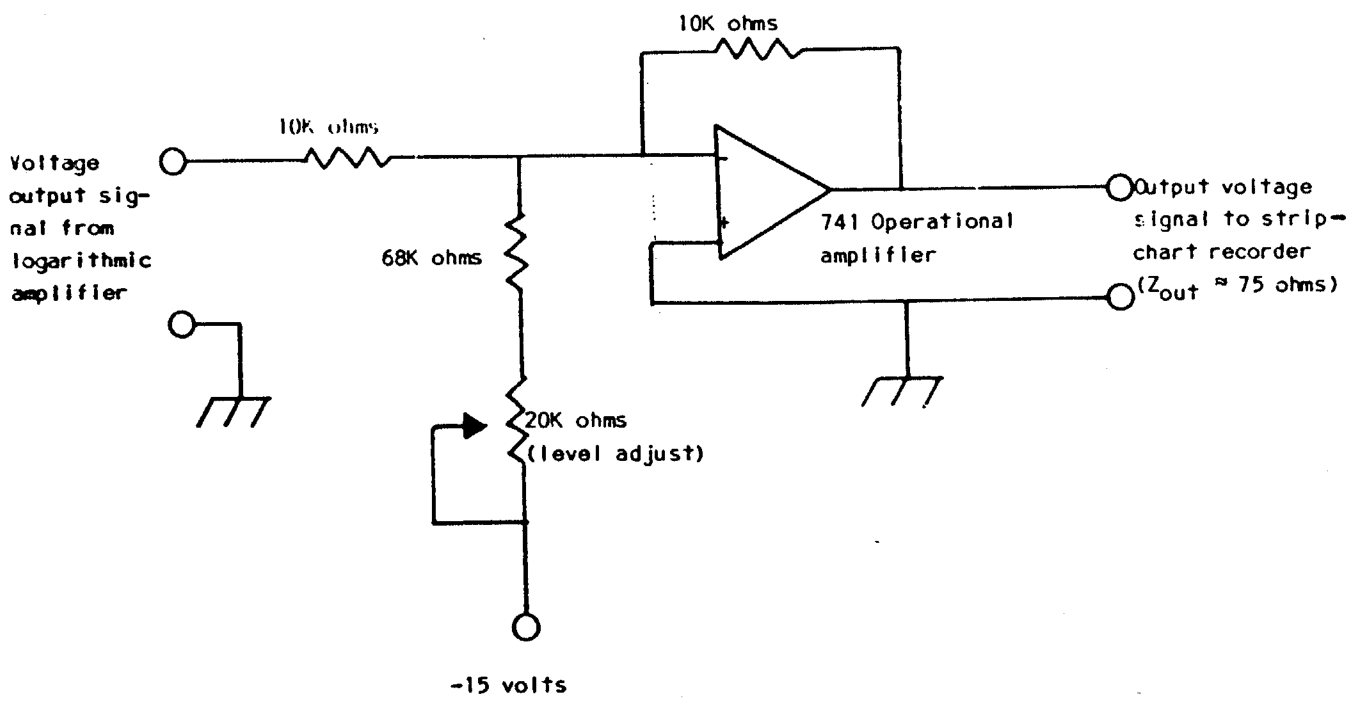

Figure 5. Strip-chart recorder interface circuit.

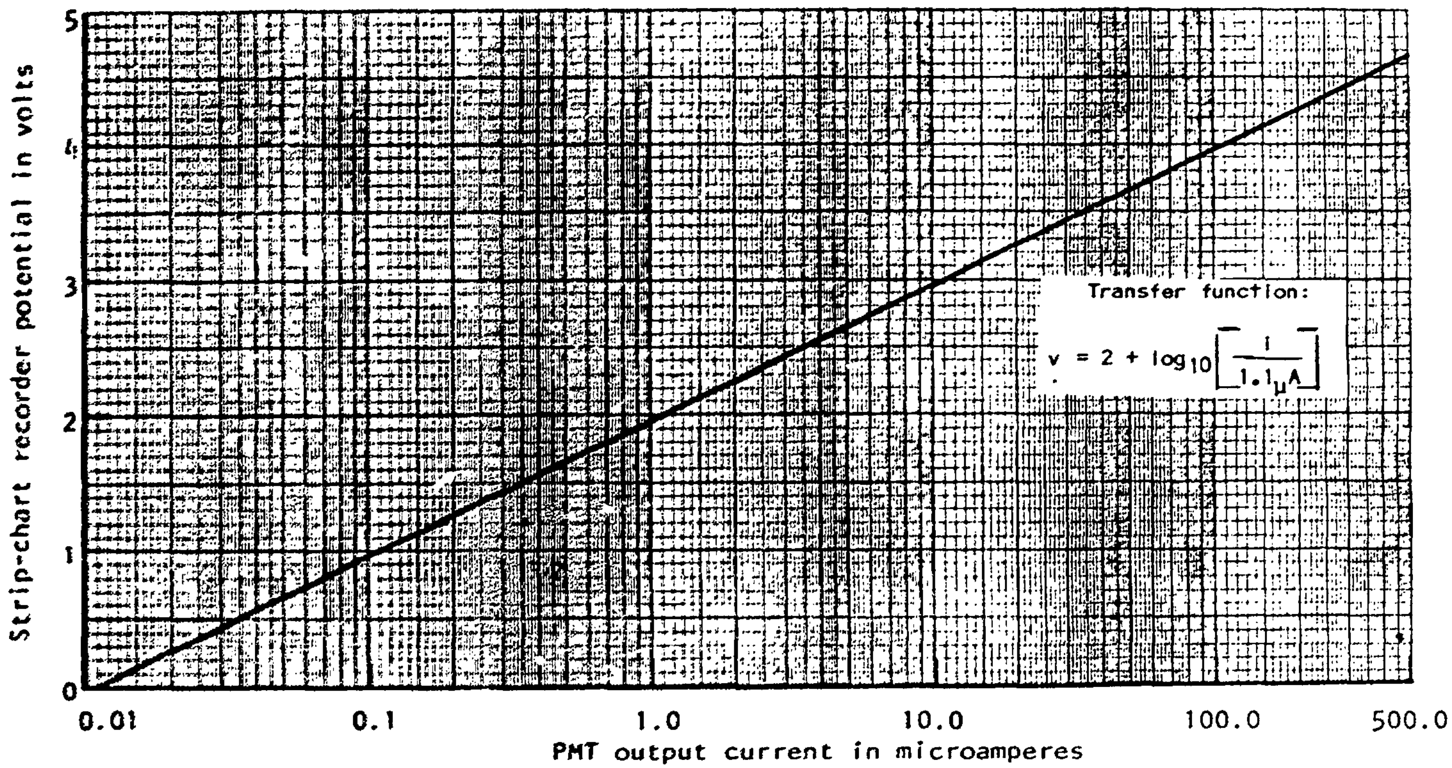

Figure 6. Transfer function plot relating PMT output current to strip-chart recorder voltage.

Calibration Procedure

The calibration procedure being used for the USAFSAM sodium chloride respirator quantitative fit test instrument utilizes the serial dilution technique [1]. This technique is based on the fact that the concentration of sodium chloride in the challenge atmosphere is directly proportional to the concentration of the sodium chloride in the atomizer solution. Thus, since a 5% sodium chloride solution standard is used to produce the challenge atmosphere, a series of dilutions of this standard can be used to produce known PMT voltage responses. If the serial dilutions are carefully selected, a series of PMT voltages, directly proportional to these concentrations, can be measured. In the end, it will be possible to interpolate between these known PMT-voltage response vs. serial-dilution concentrations, and to calculate the sodium chloride leakage (concentration) (and thus PF) based on the associated strip-chart recorder voltage fluctuations. The judicious selection of serial dilutions was made to produce calibration standards ranging from 10^{-6} to 10^{-1} of the basic 5% sodium chloride challenge atmosphere solution. Table 1 depicts the relative concentrations and component amounts [33] for the challenge/calibration sodium chloride solutions (see "Author's Note," below).

TABLE 1. SODIUM CHLORIDE CHALLENGE/CALIBRATION SOLUTIONS [Ref. 33]

Relative concentration	Mass of sodium chloride (grams)	Volume of distilled water (liters)
10^0 (5% challenge)	50.00	1.0
10^{-1}	5.000	1.0
10^{-2}	0.5000	1.0
10^{-3}	0.05000	1.0
10^{-4}	0.005000	1.0
10^{-5}	0.0005000	1.0
10^{-6}	0.00005000	1.0

When calibrating the instrument, to avoid contaminating a weaker solution by a stronger one, the operator begins with an atomizer containing the 10^{-6} solution and advances to the 10^0 solution. The strip-chart voltage amplitude for each calibration sample is annotated and retained for subsequent analysis. A typical plot (semilogarithmic) of the PMT output voltage response for each of the sodium chloride concentration standards is illustrated in Figure 7; and Table 2 depicts this relationship with actual data.

AUTHOR'S NOTE: The dual function of the 10^0 NaCl solution is to serve as a calibration solution and the challenge solution.

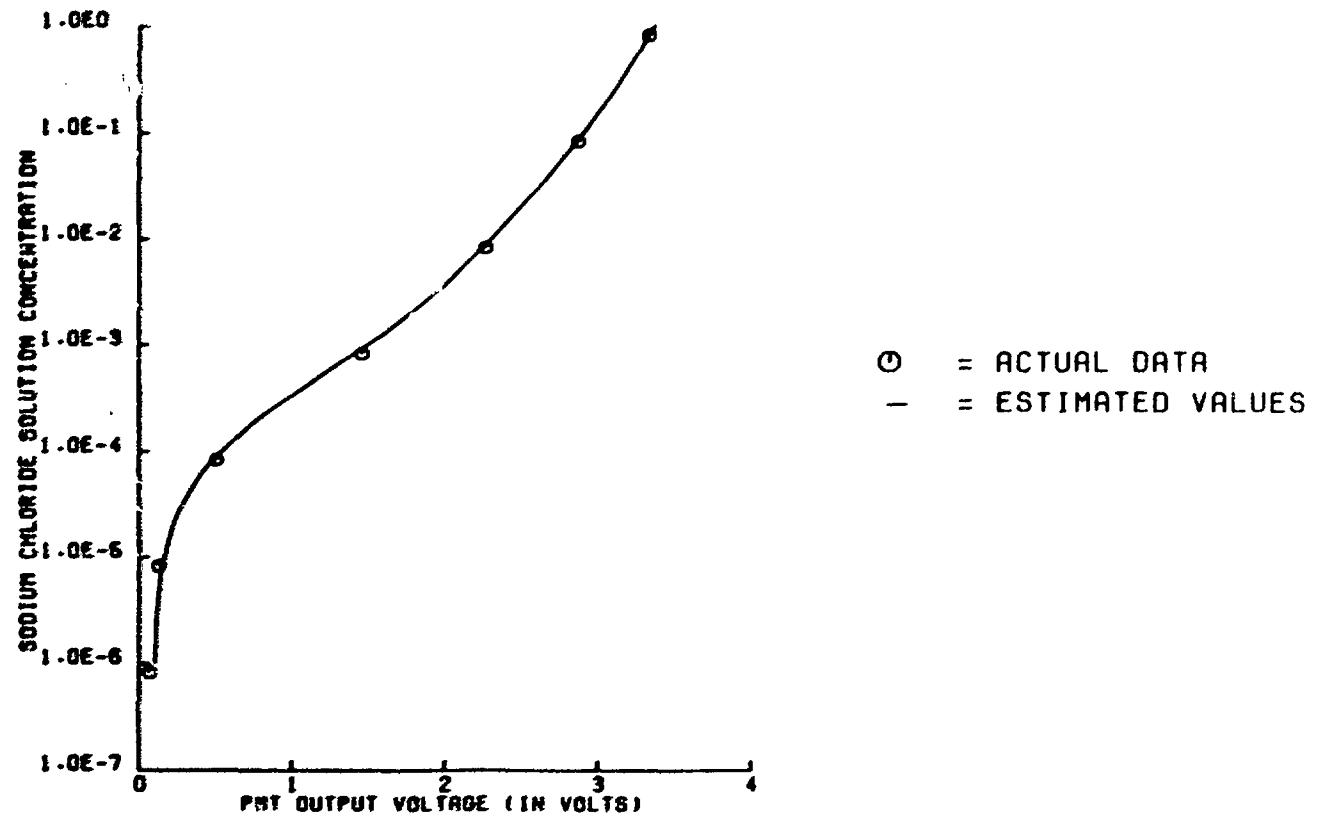

Figure 7. Sodium chloride calibration/challenge concentration vs. PMT output voltage (semilogarithmic plot).

TABLE 2. SODIUM CHLORIDE CHALLENGE/CALIBRATION SOLUTION CONCENTRATION VS. PMT OUTPUT VOLTAGE

Sodium chloride challenge/ calibration solution concentration	PMT output voltage (volts)
10^{0} (5% challenge)	3.355
10^{-1}	2.915
10^{-2}	2.310
10^{-3}	1.500
10^{-4}	0.545
10^{-5}	0.165
10^{-6}	0.105

CONVENTIONAL PROTECTION FACTOR CALCULATIONS

A general discussion of a protection factor is presented here, along with a description of the conventional method (hand calculation) used to calculate the PF's associated with aircrew chemical defense respirator quantitative fit testing. Through this information, the reader can evaluate the respective advantages and disadvantages of the conventional and automated methods of calculating PF's.

Protection Factor

A respiratory protection factor is defined as the ratio of the ambient challenge atmosphere concentration external to the respiratory protective device to that of the sampled leakage concentration drawn from the interior of the device [1,2,8,11-20,26,32,34,37,41-43]. Formally, this relationship can be expressed in mathematical terms:

$$PF = \frac{C_a}{C_s} \tag{2}$$

where

PF = protection factor

C_a = ambient challenge atmosphere concentration

C_s = sampled leakage concentration

Note that a PF is a dimensionless quantity. In the ratio, the units of concentration in the numerator and denominator cancel (assuming that C_a and C_s were measured and appropriately converted to a consistent set of concentration units; e.g., parts per million, micrograms per liter, percent, etc.).

Also important in respirator quantitative fit testing is the calculation of an average protection factor ($\overline{PF}$). This calculation becomes important when

the subject being evaluated performs a series of breathing and head movement exercises, each of which is designed to stress the face-to-facepiece seal. In mathematical terms:

$$\overline{PF} = \frac{\sum_{i=1}^{n} PF_i}{n} \tag{3}$$

where

$\overline{PF}$ = average protection factor for n exercises

i = the i^{th} exercise, i = 1, 2, 3, ..., n

PF = protection factor associated with a particular exercise

Similarly, an average weighted protection factor can be calculated when greater or lesser degrees of relative importance are assigned to individual exercise PF's. The most common example is that in which each exercise in an exercise protocol is performed for a different length of time; in this case, time would become the weighting factor. For completeness, a mathematical expression for an average weighted PF is:

$$\overline{PF_w} = \frac{\sum_{i=1}^{n} w_i \, PF_i}{\sum_{i=1}^{n} w_i} \tag{4}$$

where

$\overline{PF_w}$ = weighted average protection factor for n exercises

i = the i^{th} exercise, i = 1, 2, 3, ..., n

w_i = weighting factor for the i^{th} exercise

PF = protection factor associated with a particular exercise

Conventional Method of Calculating a Protection Factor

The USAFSAM instrument, as well as most of the similar systems, does not display, record, or calculate PF's. The instrument does, however, record and display the relative penetration (leakage) of the challenge atmosphere. The calculation of PF's for the USAFSAM instrument can be explained through an example. Shown in Figure 8 is a typical quantitative fit test strip-chart recording that includes the preliminary calibration and penetration information for a set of six exercises:

a. normal breathing (NB)

b. deep breathing (DB)

c. turning head side-to-side with deep breathing (TH)

d. moving head up-and-down with deep breathing (UD)

e. talking (T)

f. facial grimacing (FG)

The analysis of Figure 8 begins at the bottom of the strip-chart recording. The first section of information uniquely identifies the particular subject and type of respirator. The next section contains the instrument calibration data (a steady-state response measurement is recorded for each of the serial dilutions and the 5% or 10^0 sodium chloride challenge concentration). Before the breathing exercises begin, a zero calibration or washout measurement is taken to establish a baseline. The six exercises follow in sequence, each being performed for a predetermined time period.

The cyclic nature of the recorder's trace during the exercises is a direct function of the subject's breathing cycle. Figure 8, for instance, reveals that the slight negative pressure created in the facepiece during inhalation increases the penetration of the challenge atmosphere. Exhalation, on the other hand, creates a slightly positive pressure, and acts to reduce the penetration of the challenge atmosphere. Because samples are drawn from the visual cavity of chemical defense respirators, absorption of the sodium chloride aerosol by the lungs is negligible [1]. Therefore, respirator performance is based on the average of the penetration peaks and valleys for each of the exercises. Finally, the overall respirator performance is based on the arithmetic average of the six exercise PF's.

The average of the penetration peaks and valleys (location of their midpoint) is generally deduced visually. By considering each exercise separately, a line can be drawn through the "visual average" of the peaks and valleys. This midpoint line is then extended until it intersects the calibration curve (Fig. 8). A plot of the sodium chloride calibration concentrations vs. their strip-chart recorder displacements reveals an approximate logarithmic relationship (Fig. 9). Thus, logarithmic interpolation is used to identify the average penetration value between adjacent calibration decades. Presented in Table 3 is a summary of the calculations for the example in Figure 8.

TABLE 3. QUANTITATIVE FIT TEST PENETRATION RECORD

Exercise	Average penetration
Normal breathing	5.5×10^{-5}
Deep breathing	7.7×10^{-5}
Turning head side-to-side (deep breathing)	7.2×10^{-5}
Moving head up-and-down (deep breathing)	5.5×10^{-5}
Talking	5.9×10^{-5}
Facial grimacing	8.3×10^{-5}

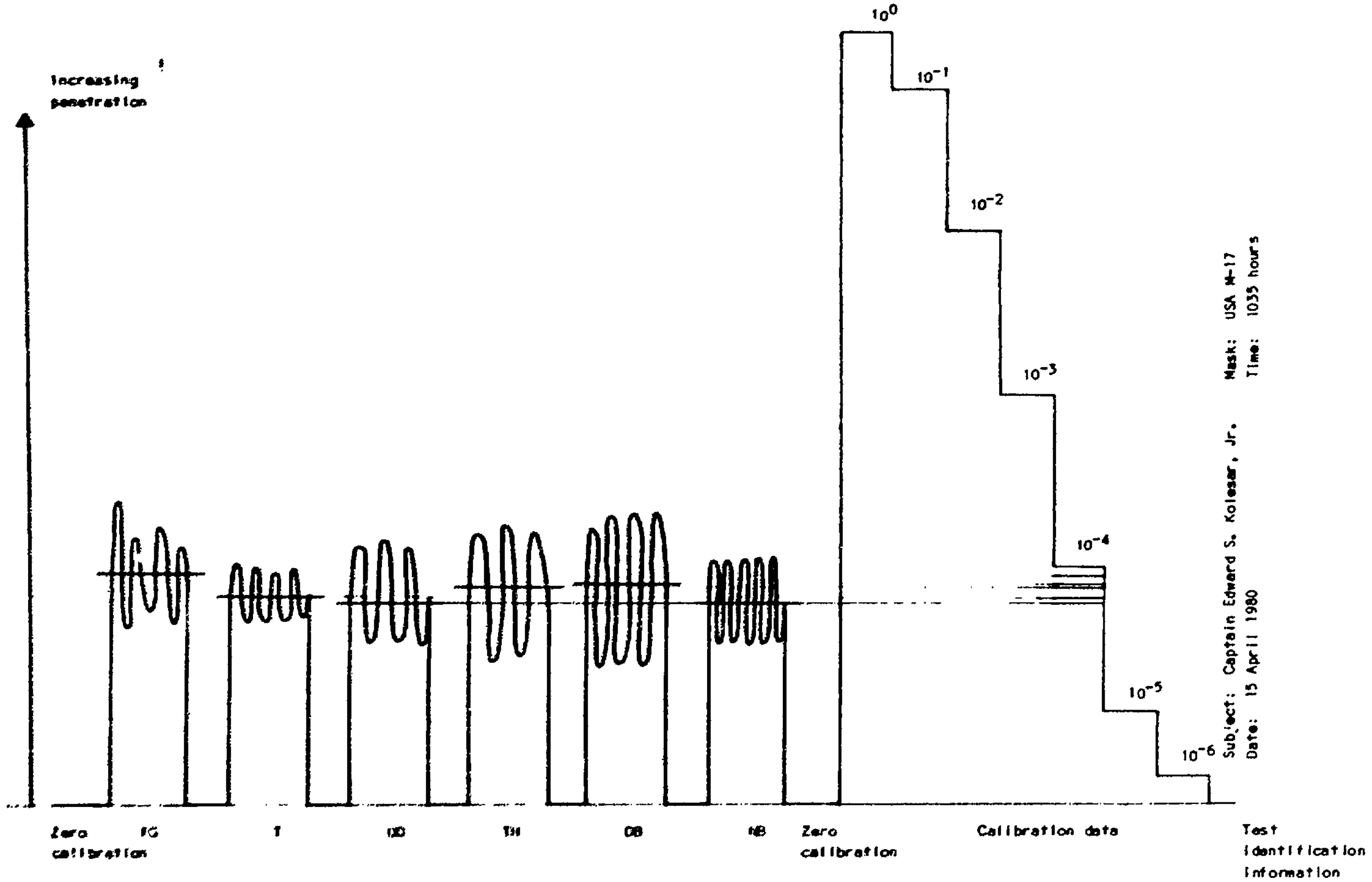

Figure 8. Strip-chart recording of sodium chloride respirator quantitative fit test.

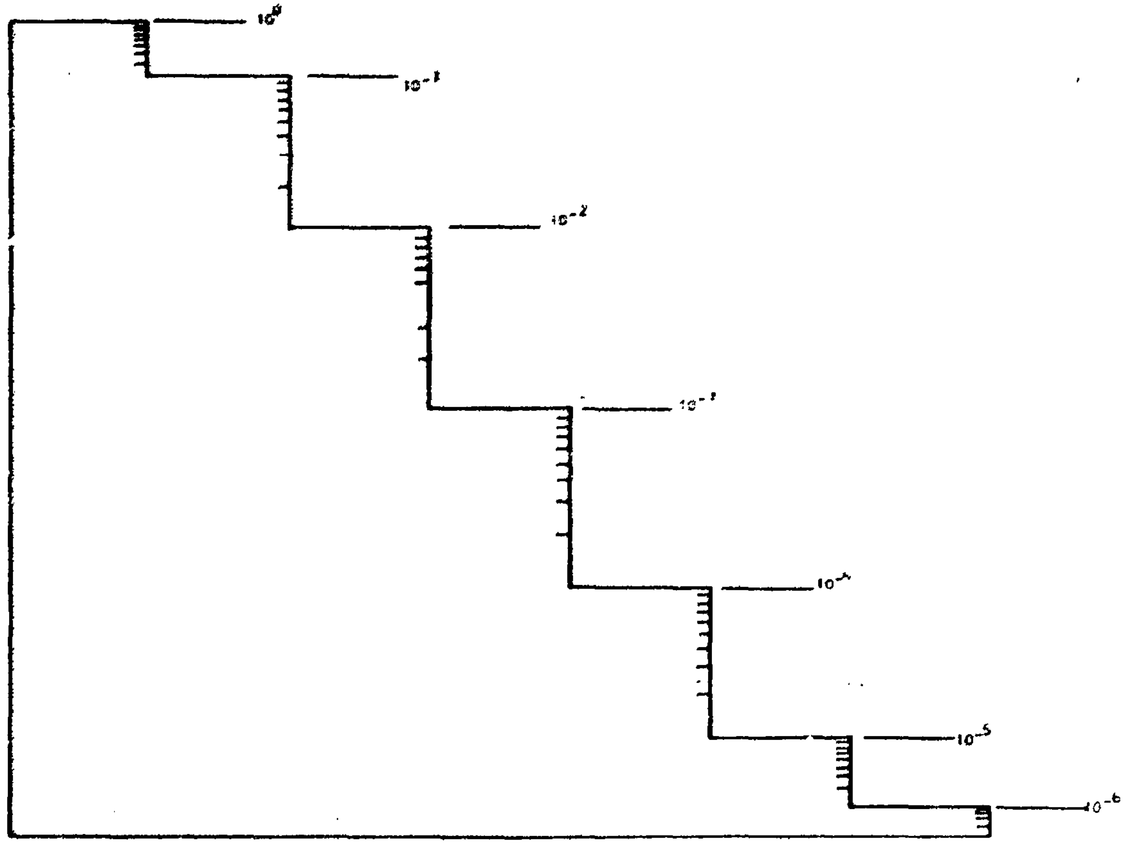

Figure 9. Sodium chloride logarithmically scaled calibration data set used to interpolate mask leakage concentration.

With this information, the PF for each exercise can be calculated using the following relationship:

$$PF = \frac{C_a}{C_s} = \frac{10^0}{C_s} = \frac{1}{C_s} \tag{5}$$

That is, since the challenge atmosphere is generated from the 5% or 10^0 sodium chloride solution concentration, and $10^0 \equiv 1$, it follows that a PF is simply the reciprocal of the exercise average penetration. To complete this example, Table 4 depicts the calculated exercise PF's and the overall arithmetic average PF.

TABLE 4. QUANTITATIVE FIT TEST PF RECORD

Exercise	PF
Normal breathing	1.8×10^4
Deep breathing	1.3×10^4
Turning head side-to-side (deep breathing)	1.4×10^4
Moving head up-and-down (deep breathing)	1.8×10^4
Talking	1.7×10^4
Facial grimacing	1.2×10^4

Overall average PF = 1.5×10^4

Although the strip-chart recorder data can be interpreted without significant mathematical rigor, this exercise can be exasperating when more than a dozen subjects are involved. Having analyzed a series of 13 tests, this author has developed an alternative method that utilizes the USAFSAM PDP-11/70 computer to perform these calculations. This automated scheme yields a data reduction turn-around time of approximately 4 min per subject vs. 40 min per subject by manual calculation.

USING A VOLTAGE-TO-FREQUENCY CONVERTER CIRCUIT TO DO TIME-AVERAGED INTEGRATION

Various techniques have been applied to integrate electronic signals produced in the laboratory. These techniques include the: ball and disk mechanical; low-inertia motor; electrochemical; analog-to-digital conversion followed by counting; operational amplifier; and voltage-to-frequency (V/F) conversion followed by counting [63]. The first four techniques have been evaluated by numerous investigators for processing laboratory-type recorded signals. Such integrators, however, possess certain inherent disadvantages; e.g., high cost, indirect readout, insufficient accuracy and precision, and insufficient dynamic range.

Operational Amplifier Integrators

Operational amplifier integrators have been used to solve the short-term laboratory signal integration problem [44-50,53,56,68,62-64]. A typical operational amplifier integrator circuit is shown in Figure 10 [64]. The output voltage of the circuit (E_{out}) is related to the input voltage (E_{in}) by Equation 6.

$$E_{out} = -\frac{1}{RC}\int_0^t E_{in}\,dt + \frac{1}{C}\int_0^t i_b^-\,dt + \frac{1}{C}\int_0^t i_{R_C}\,dt + \frac{1}{RC}\int_0^t E_{os}\,dt \quad (6)$$

The first term of Equation 6 represents the desired integrated value; and the second through fourth terms represent the output error generated by integrating the input bias current (i_b^-), the current leakage through the integrating capacitor (i_{R_C}), and the offset voltage (E_{OS}), respectively. These errors can be minimized by restricting the period of integration from 1 msec to 100 sec [51,52,54,55,59,70]. However, when the integrating period approaches 100 sec and an overall 1% accuracy is desired, a large value, high-performance, expensive polystyrene capacitor is required, as well as an expensive operational amplifier whose input offset current and drift are negligible. In order to optimize accuracy, to integrate signals lasting from milliseconds to hours, and to keep the cost of components within manageable limits, the V/F integrator scheme becomes an extremely attractive alternative [69,71-73].

Voltage-to-Frequency Converter Integrators

The basic function of a V/F converter is to transform a variable direct-current voltage (usually 0 to 10 volts) into a pulse train whose repetition rate (frequency) is a direct linear function of the direct-current input voltage. An excellent technique for precisely integrating an analog voltage signal is simply to add a counter stage to the output of a V/F converter and accumulate the pulse count. By accumulating the V/F converter output pulses, the "area under the input voltage curve," or integral, is calculated. This operating principle [68,69] is illustrated in Figure 11 In addition, digital integrators using V/F's have three primary advantages over their operational amplifier counterparts--for it is very easy to:

a. simply switch the counter to a "hold" position, and the accumulated count (integrated value) is held indefinitely with absolutely no drift;

b. preset the digital counter to any desired level and integrate up (or down) from that initial condition; and

c. adapt standard electro-optical readouts (such as Nixie tubes, light-emitting diodes, etc.) to display the integrated count value.

The attractive features of the V/F integration technique stimulated the development of the integrator used with the USAFSAM RQFT sodium chloride instrument.

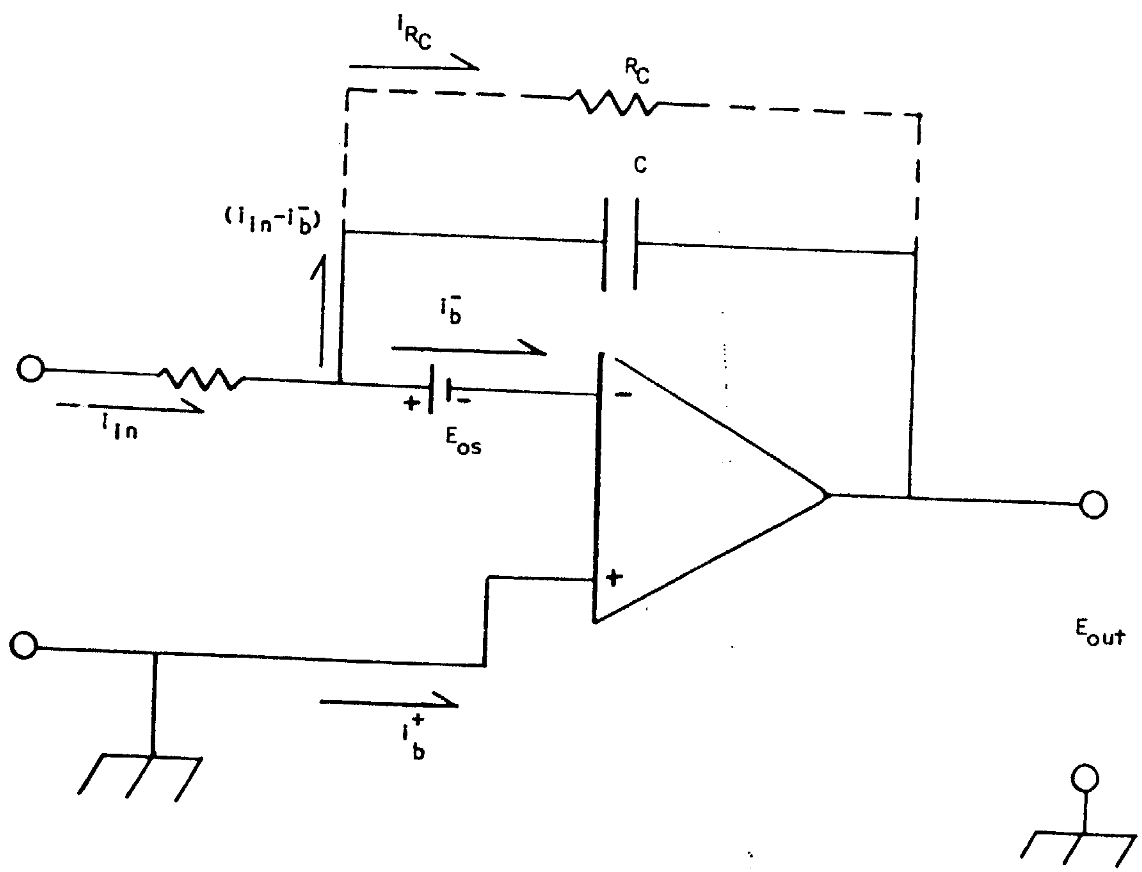

Figure 10. Typical operational amplifier integrator circuit.

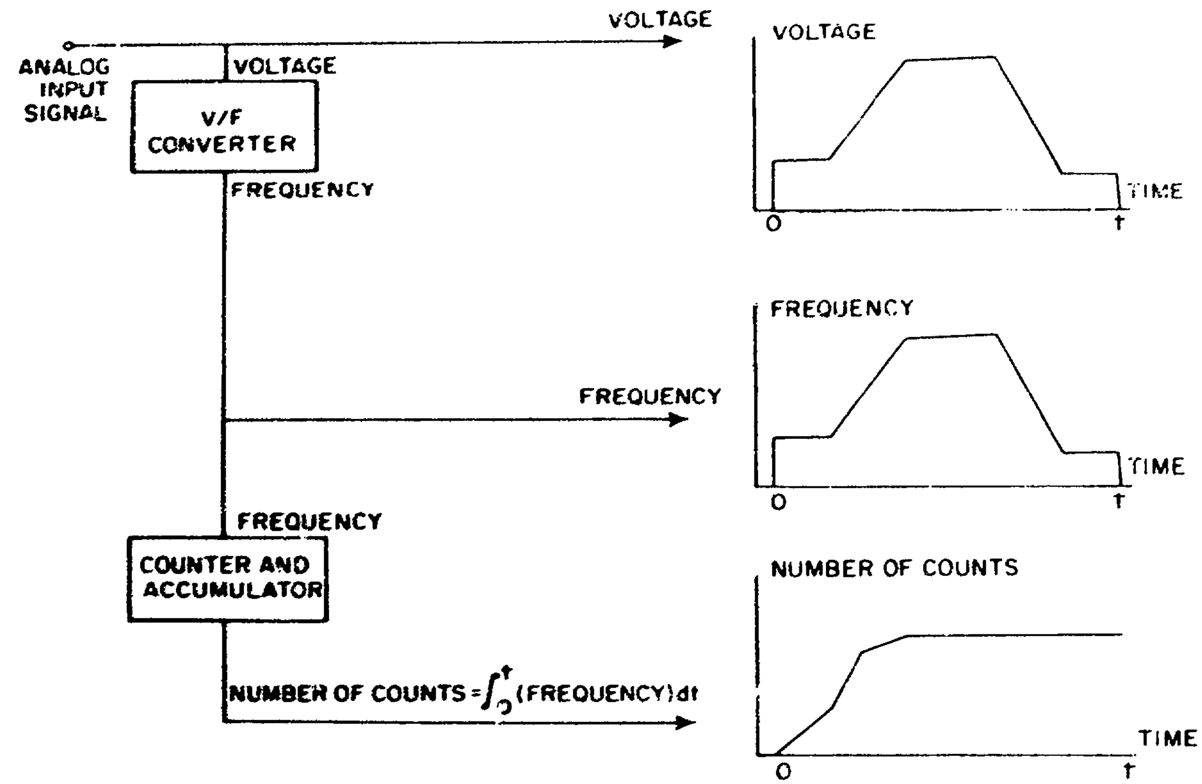

Figure 11. Operating principle of a V/F integrator.

USAFSAM Sodium Chloride RQFT Voltage-to-Frequency Integrator Circuit Design

Shown in the respective figures are the schematic diagrams for: the USAFSAM sodium chloride RQFT instrument (Fig. 12); the digital display (Fig. 13); and the voltmeter (Fig. 14). The major components [66,67,74-82] are listed in Table 5.

TABLE 5. MAJOR COMPONENTS OF THE V/F CONVERTER ELECTRONIC INTEGRATOR

Schematic Diagram References (Figs. 12 - 14)	Description
R1	27K ohms, 1/4 W, 5%
R2	1K ohms, 1/4 W, 5%
R3	20K ohms, 1/4 W, 5%
R4	500-ohm variable potentiometer
R5	50K-ohm variable potentiometer
R6	100K ohms, 1/4 W, 5%
R7	100K ohms, 1/4 W, 5%
R8	50K ohms, 1/4 W, 5%
R9	100K ohms, 1/4 W, 5%
R10	50K ohms, 1/4 W, 5%
R11	100K ohms, 1/4 W, 5%
R12	100K ohms, 1/4 W, 5%
R13	15K ohms, 1/4 W, 5%
R14	10K ohms, 1/4 W, 5%
R15	1K ohms, 1/4 W, 5%

(Cont'd. on facing page)

TABLE 5 (Cont'd.)

Schematic diagram references (Figs. 12 - 14)	Description
R16	100K-ohm variable potentiometer
R17	10K ohms, 1/4 watt, 5%
C1	0.1-μF capacitor
T1	2N956 NPN transistor
IC1	Precision Monolithics Incorporated, operational amplifier, OP-7
IC2	Analog Devices Incorporated, high performance V/F converter, AD450J
IC3	Motorola Semiconductor Products Incorporated, decade counter/divider, MC14017B
IC4	Motorola Semiconductor Products Incorporated, noninverting hex buffers, MC 14050B, V_{CC} - Pin 1, V_{SS} - Pin 8, Ground Pins 11 and 14, V_{CC} = +5 volts
IC5	Motorola Semiconductor Products Incorporated, quad 2-input OR gate, MC14071B, V_{CC} - Pin 14, V_{SS} - Pin 7, Ground Pins 5, 6, 7, 8, 9, 12, and 13, V_{CC} = +5 volts
IC6	Texas Instruments Incorporated, hex inverter, SN7404, V_{CC} - Pin 14, V_{SS} - Pin 7, V_{CC} = +5 volts
IC7	Motorola Semiconductor Products Incorporated, industrial time base generator, MC14566B
Digital Display Module - Integrator Count	Dialight LED display module 749-1706
Digital Display Module - Integration Time	Dialight LED display module 749-1704

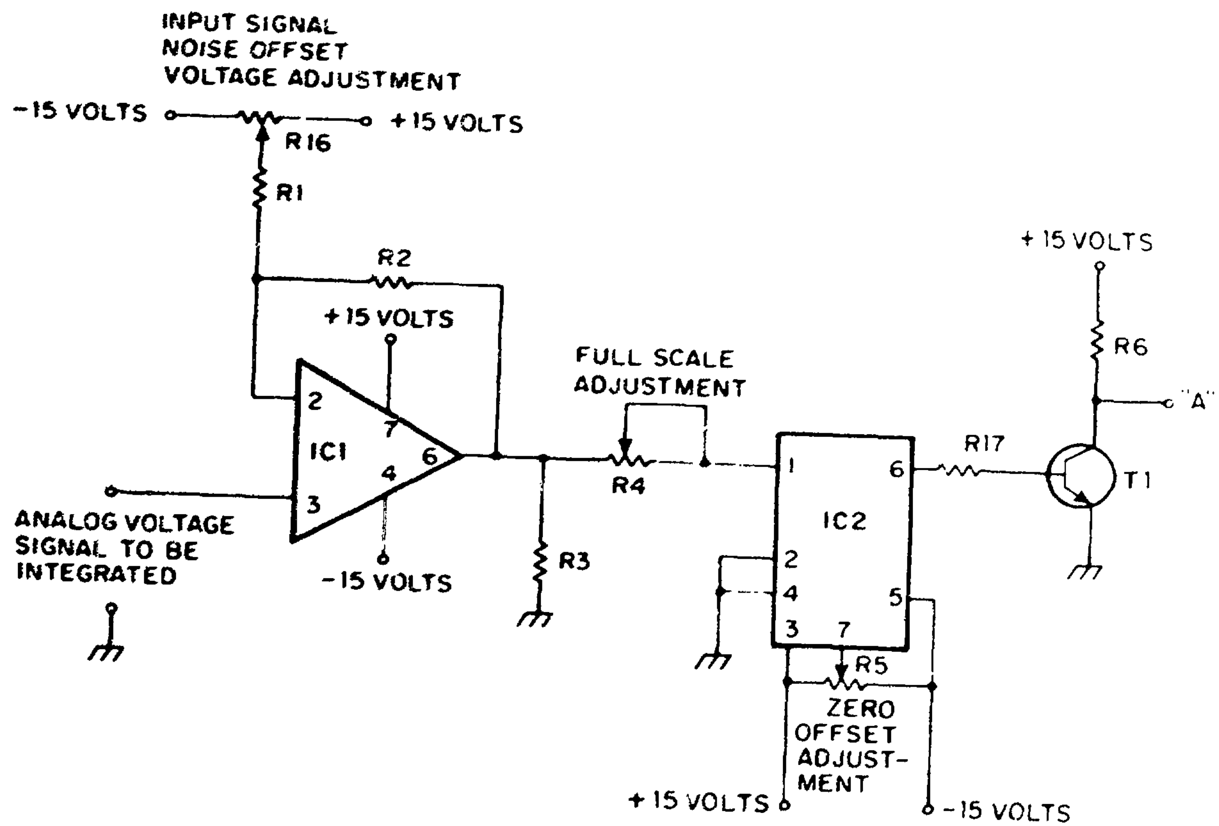

Figure 12: Part 1 (of 3). Sodium chloride RQFT instrument integrator.

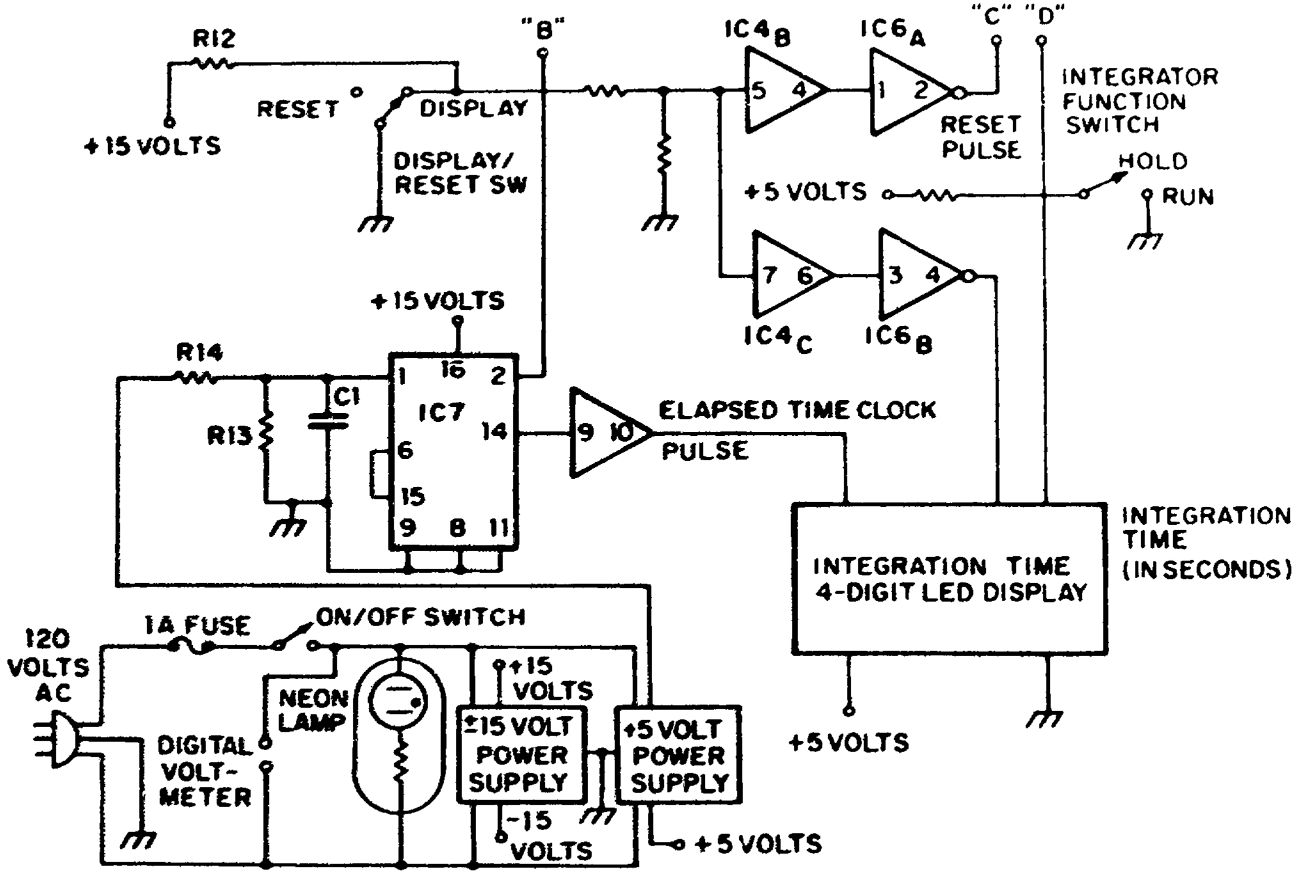

Figure 12: Part 2 (of 3). Sodium chloride RQFT instrument integrator.

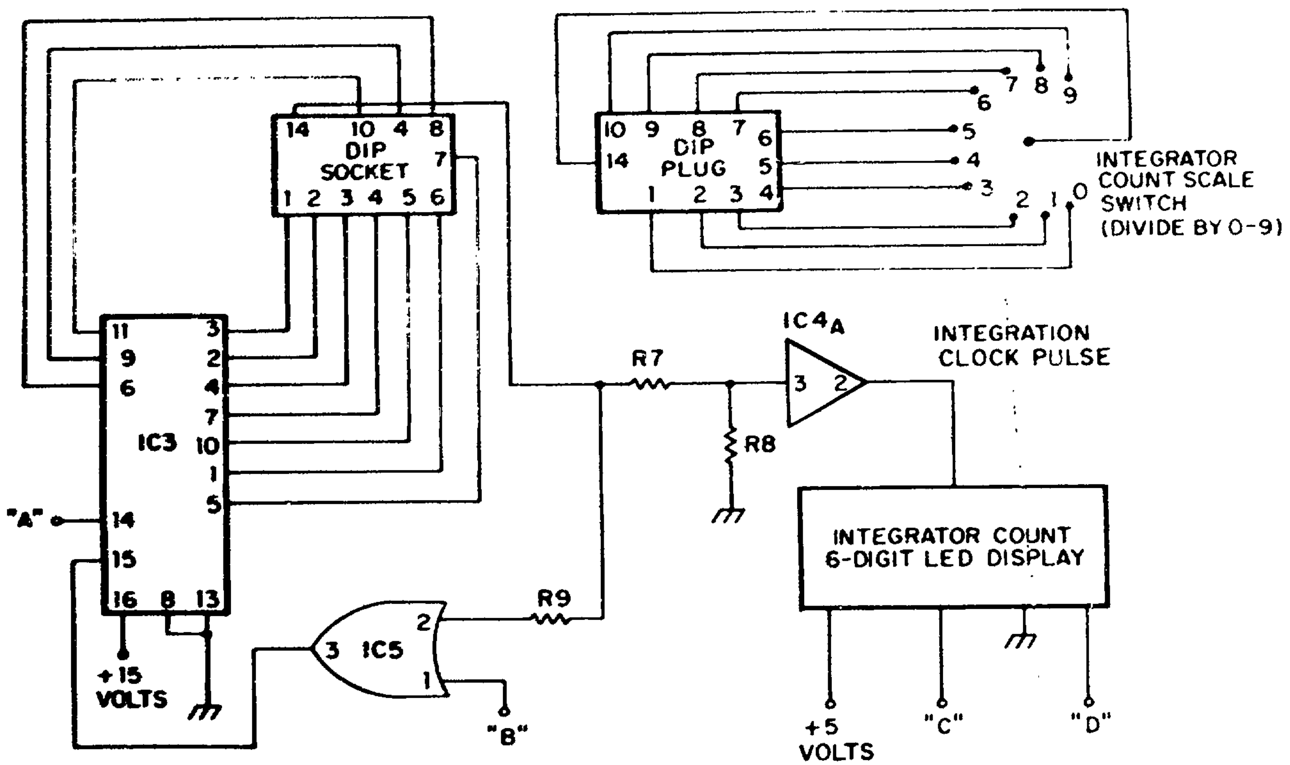

Figure 12: Part 3 (of 3). Sodium chloride RQFT instrument integrator.

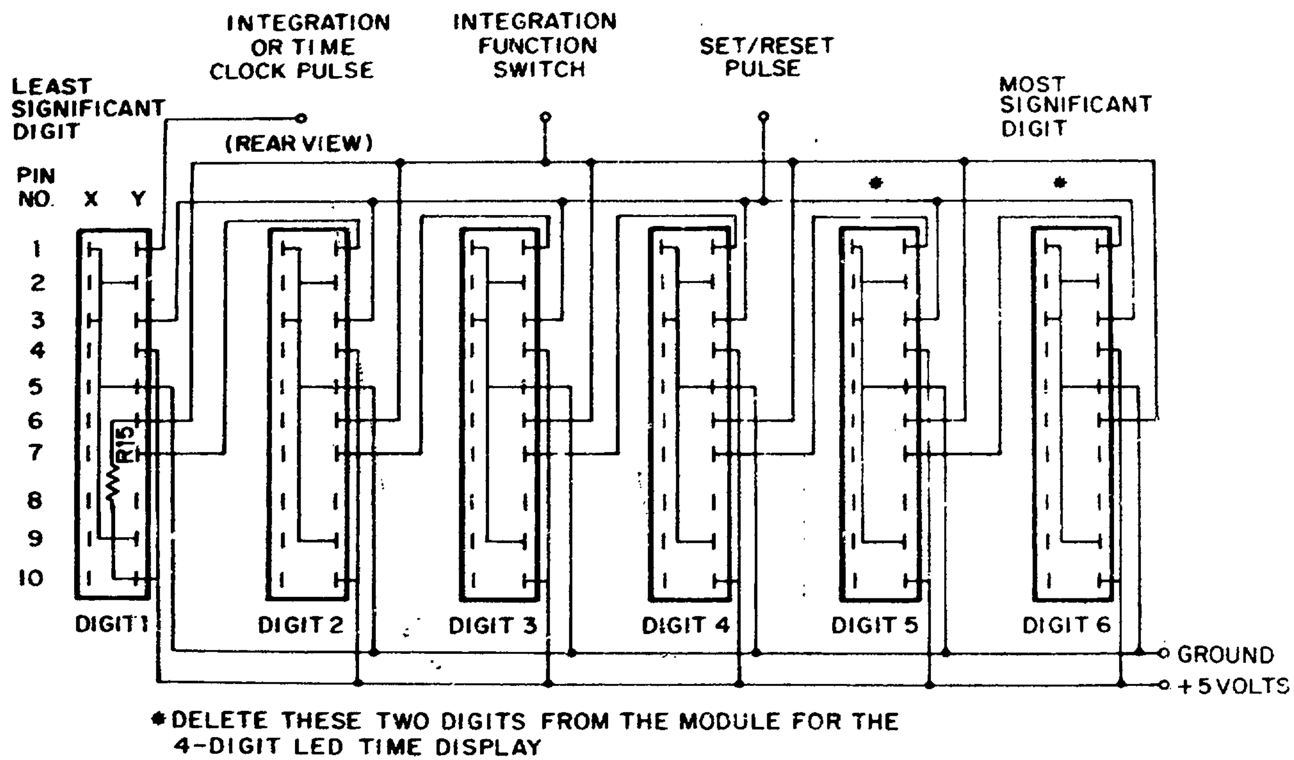

Figure 13. Sodium chloride RQFT instrument integrator digital display.
(*Delete these two digits from the module for the 4-digit LED time display.)

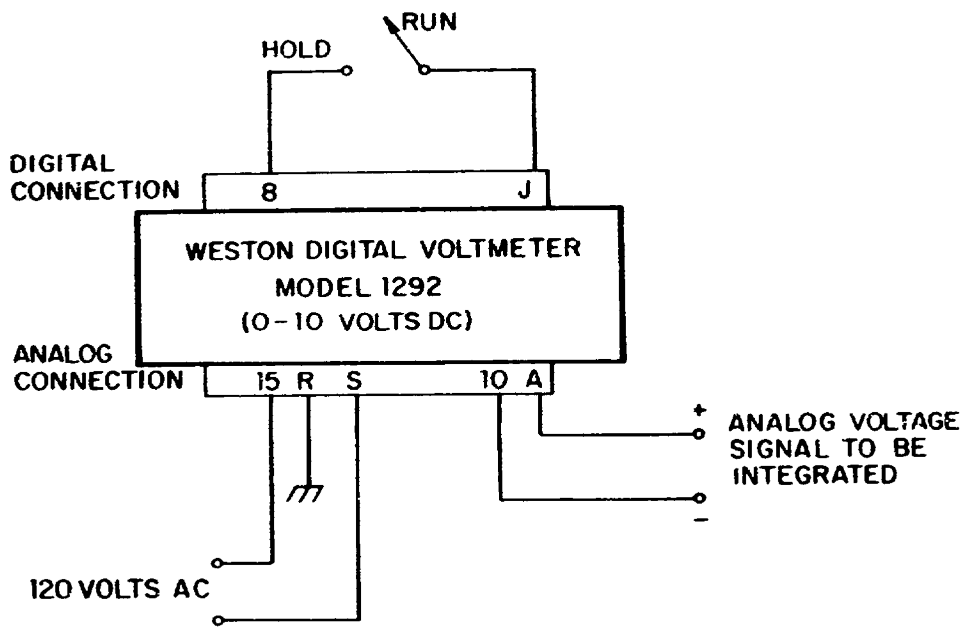

Figure 14. Sodium chloride RQFT instrument integrator voltmeter.

Description of the Analog Devices AD450J V/F Converter Integrated Circuit

The heart of the USAFSAM sodium chloride RQFT instrument integrator design is the Analog Devices AD450J V/F converter. The electronic specifications for this device [66,67,78] are summarized in Table 6, and a block diagram of the converter is shown in Figure 15 [66,67,78].

The AD450J is a low-cost high-performance V/F converter that provides exceptional linearity and temperature stability over a wide dynamic input signal range. The key to the AD450J's precise operation is the unique charge balance conversion technique. This feature means that an analog signal is accurately converted to a train of pulses (each of which has a constant width and amplitude) at a rate directly proportional to the analog signal amplitude. The output continuously tracks and responds directly to changes in the input signal.

The versatile operational amplifier buffer serves as the input stage. Its purpose is to convert the applied input voltage to a control current for the charge balance conversion circuitry.

External clock synchronization is not required for the AD450J. The internal temperature compensated timing reference yields an accurate square-wave output pulse train void of low-frequency cycle-to-cycle jitter.

Finally, the output drive circuitry is responsible for conditioning the stable output pulse train. The high current-handling capacity of this circuitry allows the designer to interface directly with any low-cost digital processing logic family. These attractive features motivated the selection of the AD450J as the V/F converter circuit for the long-term precision integrator design.

Operation of the USAFSAM Sodium Chloride RQFT V/F Integrator

Operation of the USAFSAM sodium chloride RQFT V/F integrator is quite simple. The integrator's capability and function can be appreciated by analyzing Figure 12. Only one connection to the integrator is required. The analog voltage signal to be integrated (the input signal to the strip-chart recorder) is connected directly to the 0-10 volt integrator input terminal.

The integrator is energized with the on/off switch, and the front panel neon lamp yields a positive indication for applied power. Two direct-current power supplies (±15 volt and +5 volt) provide the operating voltages for the integrator's digital circuits.

Because the output signal of the sodium chloride RQFT instrument is biased with a low-level noise component, a Precision Monolithics Corporation OP-7 operational amplifier buffer is used to compensate for this unwanted signal [74]. The degree of compensation is accomplished by rotating the PMT noise offset voltage adjustment potentiometer (R16). This adjustment must be checked each time the RQFT instrument is turned on.

TABLE 6. ELECTRONIC SPECIFICATIONS OF THE ANALOG DEVICES AD450J V/F CONVERTER

Characteristic	Value
TRANSFER FUNCTION	
Voltage Input	$f_{out} = (10^3 \frac{Hz}{V})e_{in}$
ANALOG INPUT	
Voltage Signal Range (e_{in})	0 to +10V min
Overrange	50% min
Impedance (e_{in})	20kΩ
Max Safe Input Voltage (e_{in})	+25V ($-V_s$)
ACCURACY	
Warmup Time	1 min
Nonlinearity	
e_{in} = +1mV to +15V	±0.01% max
Full Scale Error	(+0.5 ± 1.5)% max
Gain	
vs. Temperature (0 to 70°C)	±50ppm/°C max
vs. Supply Voltage	±200ppm/%max
vs. Time	±100ppm/day
Input Offset Voltage	±5mV max
vs. Temperature (0 to 70°C)	+50μV/°C
vs. Supply Voltage	±10ppm/%max
vs. Time	±10μV/day

(Cont'd. on facing page)

TABLE 6 (Cont'd.)

Characteristic	Value
RESPONSE	
Settling Time for +10V Step Input	120μs
Overload Recovery Time	15ms
CUTPUT	
Waveform	Train of TTL/DTL compatible pulses
Pulse Width	50μs
Rise/Fall Time	200ns
Pulse Polarity	positive
Logic "1" (High) Level	+2.4V min
Logic "0" (Low) Level	+0.4V max
Capacitive Loading	1000pF max
Fan Out Loading	10 TTL loads min
Impedance	3.3kΩ
POWER SUPPLY	
Voltage, Rated Performance	±15V dc
Voltage, Operating	±(12 to 18)V dc
Current, Quiescent	(+15, -9)mA
TEMPERATURE RANGE	
Rated Performance	0 to +70°C
Operating	-25°C to +80°C
Storage	-55°C to +85°C
CASE SIZE	(1.5 x 1.5 x 0.4) inches

DTL = diode-transistor logic; and TTL = transistor-transistor logic.

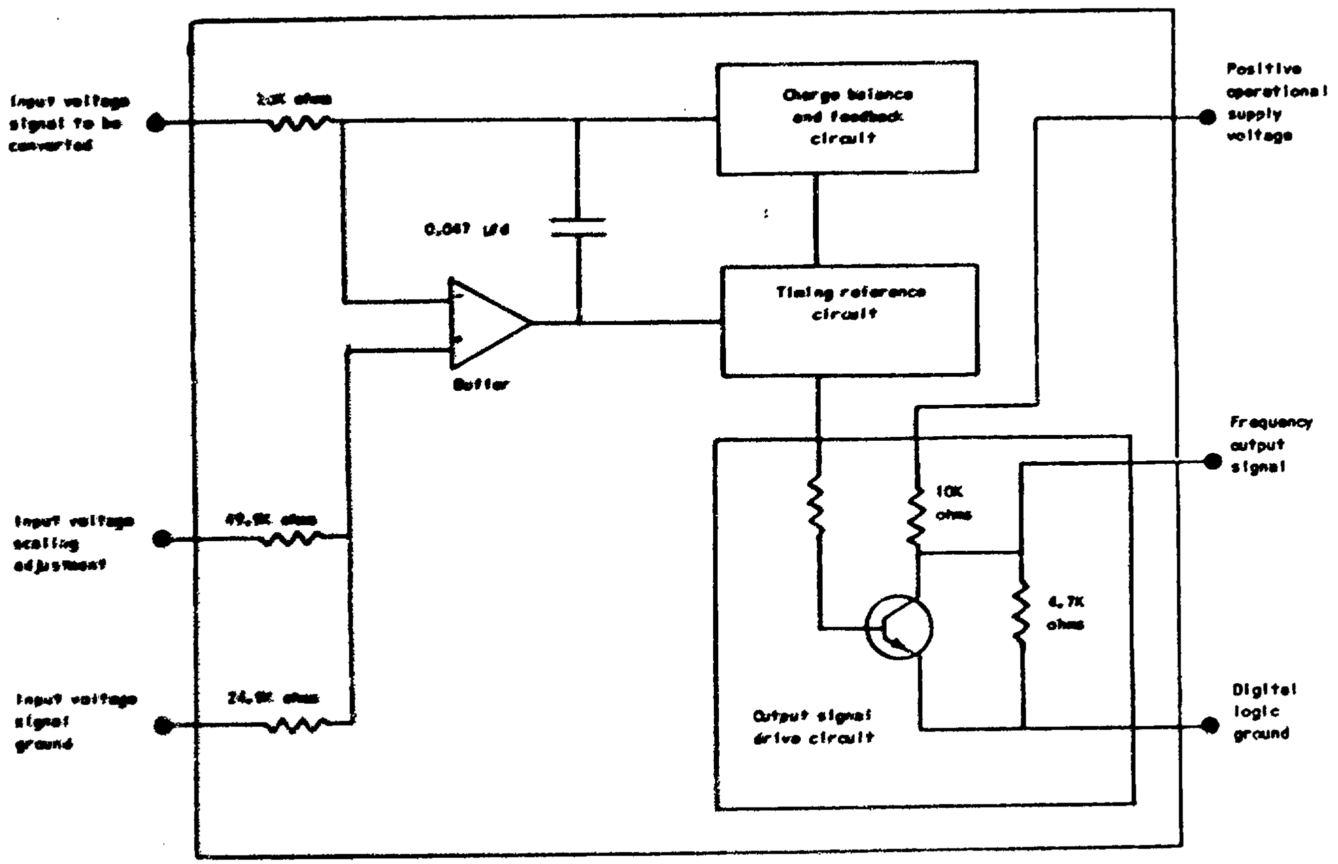

Figure 15. The Analog Devices AD450J V/F converter.

The overall accuracy and dynamic range of the AD450J V/F converter is established with an initial calibration of the two trim potentiometers (R4 and R5) shown in Figure 12. This calibration is accomplished after the integrator has reached an operating equilibrium (5-min warmup). A precision regulated voltage source of +1.00 mV is connected to pin 6 of IC1, and an oscilloscope is connected between ground and pin 6 of IC2. The zero offset adjustment potentiometer (R5) is rotated so that a 1 Hz frequency pulse train is visible on the oscilloscope. The precision regulated voltage source is then set to +10.000 V, and the full scale adjustment potentiometer (R4) is rotated so that a 10 kHz frequency pulse train is visible on the oscilloscope.

The analog input voltage-to-frequency conversion process is accomplished with the Analog Devices AD450J V/F converter. Its output pulse train is processed by the Motorola Semiconductor Products MC14017B decade counter-divider integrated circuit. This integrated circuit conditions and accumulates the V/F converter output signal for the 6-digit LED integrator count display. The user can select a signal dividing constant via the panel-mounted integrator count scale switch. Selection of the divide-by-one position means a one-to-one correspondence exists between the actual integrator count (area under the analog voltage input signal) and the magnitude on the digital display. Selection of any switch position 2 through 9 means that the magnitude on the digital display must be multiplied by the switch position number to yield the actual integrator count. This feature permits the user to integrate input signals for several hours without overloading the integrator count display.

An internal time base generator is an inherent part of the integrator design. A Motorola Semiconductor Products MC14566 integrated circuit is used to provide a clocked output pulse each second. The accumulated time (in seconds) is available via the 4-digit LED display. The user controls the length of time an analog input signal is integrated. Two front-panel mounted switches give the user the flexibility to clear both LED displays to read zero and halt the integration of a signal at any point in time. To clear the displays, the user simply toggles the display reset switch and trips the integrator function switch to the hold position. When the operator is ready to integrate a signal, he toggles the integrator function switch to the run position. Thus, the signal will be integrated and the integrator count and elapsed time will be automatically recorded on the appropriate LED displays. When the integration is to be halted, the user toggles the integration function switch to the hold position. This last operation gives the user the opportunity to record the magnitude of the integrator count and elapsed time. When another signal is to be integrated, the user resets the displays to zero and repeats the sequence described above.

Data Collection with the USAFSAM Sodium Chloride RQFT Instrument V/F Integrator

The collection of RQFT data for subsequent PF calculations is a simple process when the integrator is used. Shown in Figures 16 and 17 are the data sheets used for this purpose. After the RQFT instrument has reached its operating equilibrium, and the integrator's PMT noise offset voltage has been adjusted, the sodium chloride calibration and challenge atmosphere atomizer solutions are processed.

RESPIRATOR QUANTITATIVE FIT TESTING
--USAFSAM SALT FOG INSTRUMENTATION--

Concentration	Voltage (In Volts)				
10 to the Zero					
10 to the Minus One					
10 to the Minus Two					
10 to the Minus Three					
10 to the Minus Four					
10 to the Minus Five					
10 to the Minus Six					

SUBJECT NAME: ______________________________
TYPE OF MASK: ______________________________
DATE TESTED: ______________________________
TIME TESTED: ______________________________

Exercise	Count						Time Period (In Seconds)	
Normal Breathing Straight Ahead								
Deep Breathing Straight Ahead								
Talking								
Side-to-Side Head Movements (Deep Breathing)								
Up-and-Down Head Movements (Deep Breathing)								
Facial Grimacing								

Figure 16. Sodium chloride RQFT data collection form No. 1.

RESPIRATOR QUANTITATIVE FIT TESTING
--USAFSAM SALT FOG INSTRUMENTATION--

Concentration	Voltage (In Volts)
10 to the Zero	
10 to the Minus One	
10 to the Minus Two	
10 to the Minus Three	
10 to the Minus Four	
10 to the Minus Five	
10 to the Minus Six	

SUBJECT NAME: ______________________
TYPE OF MASK: ______________________
DATE TESTED: ______________________
TIME TESTED: ______________________

Exercise	Count	Time Period (In Seconds)
Normal Breathing Straight Ahead		
Normal Breathing Left		
Normal Breathing Right		
Normal Breathing Down		
Normal Breathing Up		
Deep Breathing Straight Ahead		
Deep Breathing Left		
Deep Breathing Right		
Deep Breathing Down		
Deep Breathing Up		
Talking		
Facial Grimacing		
Side-to-Side Head Movements (Normal Breathing)		
Up-and-Down Movements (Normal Breathing)		
Side-to-Side Head Movements (Deep Breathing)		
Up-and-Down Head Movements (Deep Breathing)		

Figure 17. Sodium chloride RQFT data collection form No. 2.

The data collected for each of the standards is the steady-state output voltage displayed on the integrator's digital voltmeter. These voltages will range from a maximum of 4.0 volts to a minimum of 0.09 volts; each reading is recorded opposite the sodium chloride concentration (Fig. 16). The next block of information to be recorded is the subject and respirator identification information. After each exercise is accomplished, the integrator count on the 6-digit LED display and time on the 4-digit LED display are recorded. The elapsed-time display is used to initiate and terminate each exercise. Before proceeding to the next exercise, the integrator displays are reset to zero.

After all subjects have been tested, the user proceeds to a computer terminal and enters the information from the data collection forms. The interactive curve-fitting and PF calculation program described in the next section is used to process the RQFT data.

LEAST SQUARES CURVE FITTING COMPUTER PROGRAM TO CALCULATE PROTECTION FACTORS

The fitting of empirical data by formulas or equations can be accomplished by two methods. The first is to have a polynomial that is satisfied exactly at the observed data points; this is commonly referred to as "the polynomial interpolation method" [83,84,86-92]. The second method, however, is a more desirable way to analyze data which have been gathered from experimental observations that are biased with various errors of measurement; this is commonly referred to as "the least squares approximation method" [83-87,93]. Because the measurement errors associated with the RQFT calibration data have been empirically determined to be relatively small in magnitude, a least squares curve fitting algorithm is used to determine an interpolating polynomial. The theory of fitting nonlinear curves by the method of least squares yields an interpolating polynomial when the degree of the polynomial is one less than the number of data points. Additionally, this curve fitting polynomial is unique and the data points are fully parameterized [96]. A summary of the mathematical theory for the method of least squares curve fitting is presented first, and is followed by its direct application to process the RQFT data and calculate PF's.

The Method of Least Squares Curve Fitting

The objective of the method of least squares curve fitting is to relate by some function, $y = f(x)$, a set of m points (x_j, y_j), $(j = 1, 2, 3, \ldots, m)$, which have been gathered through some measuring process. The method of least squares curve fitting assumes that the function, $y = f(x)$, can be written as a polynomial of degree $n < m$:

$$y = a_0 + a_1 x + a_2 x^2 + \ldots + a_n x^n = \sum_{i=0}^{n} a_i x^i \quad (7)$$

The next step in the process is to determine the value of the coefficients a_i, $(i = 0, 1, 2, \ldots, n)$, such that the polynomial described by Equation 7 is a "good fit" to the data (x_j, y_j). By substituting the data points into the polynomial described by Equation 7, a set of m simultaneous equations are generated:

$$\left[\begin{array}{l} R_1 = a_0 + a_1 x_1 + a_2 x_1^2 + \ldots + a_n x_1^n - y_1 \\ R_2 = a_0 + a_1 x_2 + a_2 x_2^2 + \ldots + a_n x_2^n - y_2 \\ \vdots \\ R_m = a_0 + a_1 x_m + a_2 x_m^2 + \ldots + a_n x_m^n - y_m \end{array}\right] \tag{8}$$

These equations are not exactly equal to zero, because the polynomial does not necessarily pass through all the points (except in the case where the degree of the polynomial is one less than the number of data points). As shown in Figure 18, the differences between a polynomial value and a data value can be positive, negative, or zero. This difference is called a residual. Residuals are readily calculated by Equation 9.

$$R_j = \sum_{i=0}^{n} a_i x_j^i - y_j \quad \text{for} \quad (j = 1, 2, \ldots, m) \tag{9}$$

Thus, the set of equations described by Equation 8 can be referred to as "the residual equations." The principle of least squares curve fitting states that the best representation of the data is that which makes the sum of the squares of the residuals a minimum [83,86,87,93]. Therefore, it is desirable to force the function

$$f(a_0, a_1, a_2, \ldots, a_n) = R_1^2 + R_2^2 + R_3^2 + \ldots + R_m^2 \tag{10}$$

to be as close to zero as possible. The condition which fulfills this requirement is that the partial derivatives of Equation 10 be exactly zero [85,94].

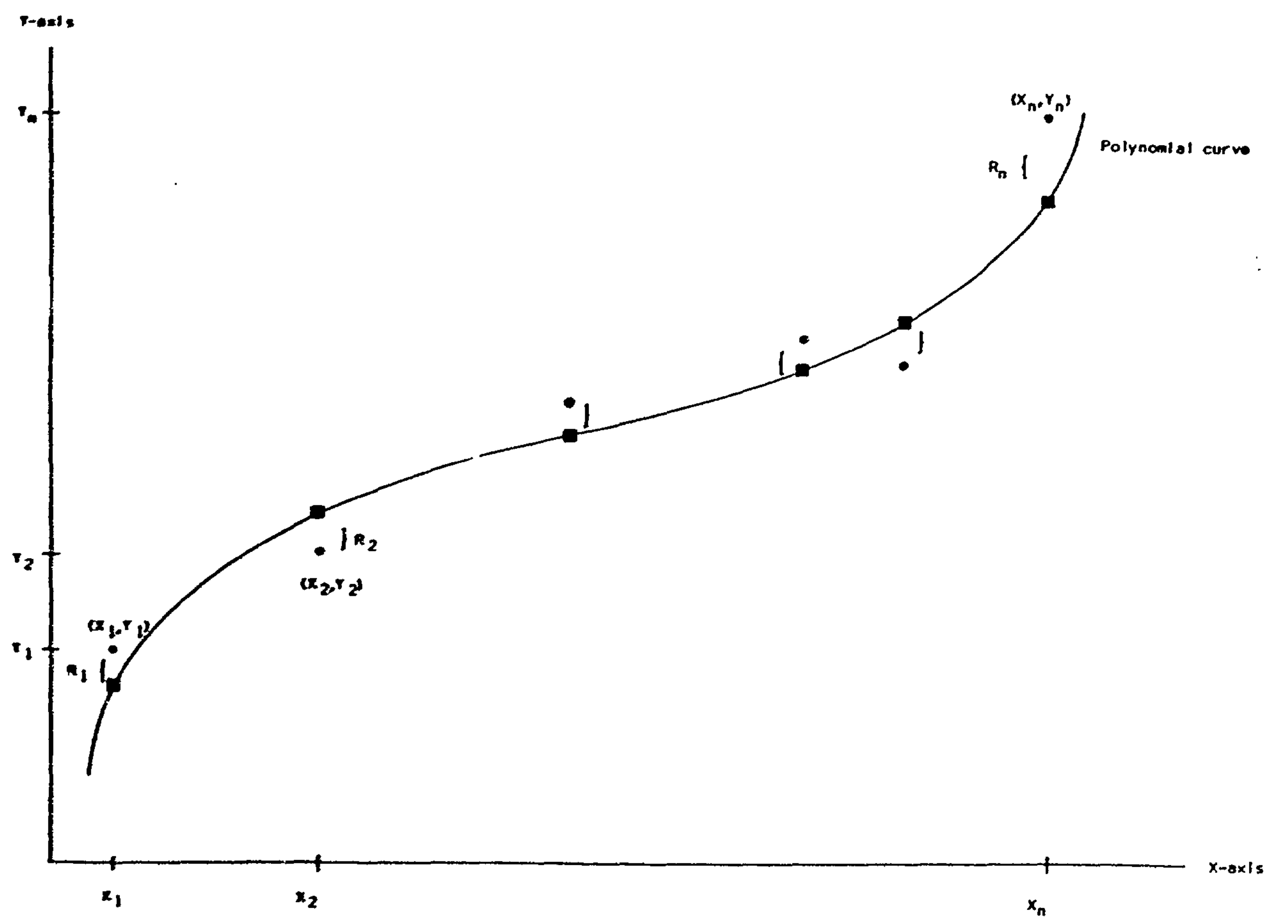

Figure 18. Concept of residuals for the method of least squares curve fitting.

Thus,

$$\left[\begin{array}{l}
\dfrac{\partial f}{\partial a_0} = 2\left[R_1 \dfrac{\partial R_1}{\partial a_0} + R_2 \dfrac{\partial R_2}{\partial a_0} + \ldots + R_m \dfrac{\partial R_m}{\partial a_0}\right] = 0 \\[2ex]
\dfrac{\partial f}{\partial a_1} = 2\left[R_1 \dfrac{\partial R_1}{\partial a_1} + R_2 \dfrac{\partial R_2}{\partial a_1} + \ldots + R_m \dfrac{\partial R_m}{\partial a_1}\right] = 0 \\[2ex]
\quad\vdots \qquad\qquad\qquad \vdots \qquad\qquad\qquad \vdots \\[2ex]
\dfrac{\partial f}{\partial a_n} = 2\left[R_1 \dfrac{\partial R_1}{\partial a_n} + R_2 \dfrac{\partial R_2}{\partial a_n} + \ldots + R_m \dfrac{\partial R_m}{\partial a_n}\right] = 0
\end{array}\right] \tag{11}$$

By taking appropriate partial derivatives for the equations in Equation 8, a new set is generated:

$$\left[\begin{array}{l}
\dfrac{\partial R_j}{\partial a_0} = \dfrac{\partial}{\partial a_0}\left[a_0 + a_1 x_j + a_2 x_j^2 + \ldots + a_n x_j^n - y_j\right] = 1 \\[2ex]
\dfrac{\partial R_j}{\partial a_1} = \dfrac{\partial}{\partial a_1}\left[a_0 + a_1 x_j + a_2 x_j^2 + \ldots + a_n x_j^n - y_j\right] = x_j \\[2ex]
\dfrac{\partial R_j}{\partial a_2} = \dfrac{\partial}{\partial a_2}\left[a_0 + a_1 x_j + a_2 x_j^2 + \ldots + a_n x_j^n - y_j\right] = x_j^2 \\[2ex]
\quad\vdots \qquad\qquad\qquad\qquad \vdots \qquad\qquad\qquad\qquad \vdots \\[2ex]
\dfrac{\partial R_j}{\partial a_n} = \dfrac{\partial}{\partial a_n}\left[a_0 + a_1 x_j + a_2 x_j^2 + \ldots + a_n x_j^n - y_j\right] = x_j^n
\end{array}\right] \tag{12}$$

in which ($j = 1, 2, 3, \ldots, m$).

Substituting the results of Equation 12 into Equation 11 yields:

$$\begin{bmatrix} R_1 + R_2 + R_3 + \ldots R_m = 0 \\ x_1R_1 + x_2R_2 + x_3R_3 + \ldots + x_mR_m = 0 \\ x_1^2R_1 + x_2^2R_2 + x_3^2R_3 + \ldots + x_m^2R_m = 0 \\ \vdots \qquad \vdots \qquad \vdots \\ x_1^nR_1 + x_2^nR_2 + x_3^nR_3 + \ldots + x_m^nR_m = 0 \end{bmatrix} \tag{13}$$

Replacing the R_j's by their values, defined in Equation 8, and collecting the coefficients of the (n+1) unknowns of a_i, (i = 0, 1, 2, 3, ..., n), yields:

$$\begin{bmatrix} ma_0 + \sum x_j a_1 + \sum x_j^2 a_2 + \ldots + \sum x_j^n a_n - \sum y_j = 0 \\ \sum x_j a_0 + \sum x_j^2 a_1 + \sum x_j^3 a_2 + \ldots + \sum x_j^{n+1} a_n - \sum x_j y_j = 0 \\ \sum x_j^2 a_0 + \sum x_j^3 a_1 + \sum x_j^4 a_2 + \ldots + \sum x_j^{n+2} a_n - \sum x_j^2 y_j = 0 \\ \vdots \qquad \vdots \qquad \vdots \\ \sum x_j^n a_0 + \sum x_j^{n+1} a_1 + \sum x_j^{n+2} a_2 + \ldots + \sum x_j^{2n} a_n - \sum x_j^n y_j = 0 \end{bmatrix} \tag{14}$$

where all summations are from 1 to m; that is,

$$\begin{bmatrix} \sum x_j^3 = x_1^3 + x_2^3 + x_3^3 + \ldots + x_m^3 \\ \sum x_j^2 y_j^2 = x_1^2 y_1 + x_2^2 y_2 + \ldots + x_m^2 y_m \end{bmatrix} \tag{15}$$

The set of equations defined in Equation 14 are known as the normal equations. All of the associated summations are known; so the system of equations

defined by Equation 14 is a system of (n+1) linear equations in the (n+1) unknowns of a_i ($i = 0, 1, 2, \ldots, n$). The solution of Equation 14 yields the coefficients, a_i, and thus the polynomial defined by Equation 7 is determined.

The principle of least squares curve fitting is not limited to polynomials defined solely in terms of x. The functional relationship between y and x can be any known form (i.e., e^x, $\log_{10}x$, $\sin x$, $1/x$, etc.) as long as the functional form is defined and the resulting normal equations can be solved. The simplest case by far, however, is for y defined directly in terms of x [83-87,93].

The coefficients for Equation 7 are found by calculating, from the measured data, all the sums defined by Equation 14. These sums are then substituted into this system of equations, and the coefficients a_i ($i = 0, 1, 2, \ldots, n$) are thus determined.

Application of the Method of Least Squares Curve Fitting to Calculate RQFT PF's

The method of least squares curve fitting was applied to process the calibration and exercise integrator count data; the final product is the calculation of PF's. The author wrote a Fortran computer program that accepted the calibration data and calculated a least squares polynomial curve fit equation. The integrator count data for each exercise was then substituted into the polynomial equation, and a corresponding mask leakage penetration (concentration) was calculated. Finally, PF's were calculated using Equation 5. The subsequent paragraphs of this report outline the analysis used to accomplish this method of calculating PF's.

The objective of writing a least squares curve fitting computer program was to take advantage of the intrinsic importance of the calibration data and relate this set of seven points (x_j, y_j), ($j = 1, 2, 3, \ldots, 7$) by some function $y = f(x)$. In this particular case, the x coordinate is the digital voltmeter reading (in volts), and the y coordinate is the corresponding sodium chloride calibration or challenge concentration. (This determination was made to avoid introducing additional error in the calculation of a PF by having to implement a complex inverse iteration algorithm.) By referring to Figure 16, the reader can observe that these seven ordered pairs correspond to the data at the top of the RQFT form. A typical set of calibration data are shown in Table 7.

After several sets of calibration data had been examined, and various functional definitions of the variable had been tried, it was determined that a polynomial of the following form yielded the best and most stable fit:

$$y = a_0 + a_1e^x + a_2(e^x)^2 + a_3(e^x)^3 + a_4(e^x)^4 + a_5(e^x)^5 + a_6(e^x)^6 \qquad (16)$$

The "goodness" of fit was checked utilizing the conditional Eq. 10 to verify that the polynomial indeed passed through the RQFT calibration data points. The computer program has calculated the "goodness" of fit; and the results for a typical run, using the data in Table 7, are presented in Table 8. In addition, a computer-generated (Calcomp) plot (semilogarithmic) is shown in Figure 19.

TABLE 7. TYPICAL SODIUM CHLORIDE RQFT CALIBRATION DATA USED FOR LEAST SQUARES CURVE FITTING

X-coordinate (voltage reading) [in volts]	Y-coordinate (sodium chloride concentration)
3.380	1.0
2.915	0.1
2.310	0.01
1.500	0.001
0.545	0.0001
0.165	0.00001
0.105	0.000001

TABLE 8. LEAST SQUARES CURVE FIT CALCULATIONS FOR THE DATA CONTAINED IN TABLE 7

The order of the desired polynomial = 6

The polynomial functional definition of the variable (X) is in terms of:
(Exponential (X))

Coefficient Number 1 = -4.17904E-05
Coefficient Number 2 = -7.31487E-05
Coefficient Number 3 = 1.25863E-04
Coefficient Number 4 = -2.68095E-05
Coefficient Number 5 = 3.80138E-06
Coefficient Number 6 = -1.71541E-07
Coefficient Number 7 = 3.88406E-09

The residuals are calculated by the following equation: [Y(DATA)-Y(ESTIMATED)]

SAMPLE NUMBER	Y(DATA)	Y(ESTIMATED)	RESIDUAL
1	1.00000	1.00000	-0.483548E-07
2	0.100000	0.100000	-0.189111E-07
3	0.100000E-01	0.100000E-01	-0.711342E-08
4	0.100000E-02	0.100000E-02	-0.401929E-08
5	0.100000E-03	0.100004E-03	-0.390294E-08
6	0.100000E-04	0.100034E-04	-0.340602E-08
7	0.100000E-05	0.100433E-05	-0.432502E-08

Sum of the square residuals = 2.80811E-15

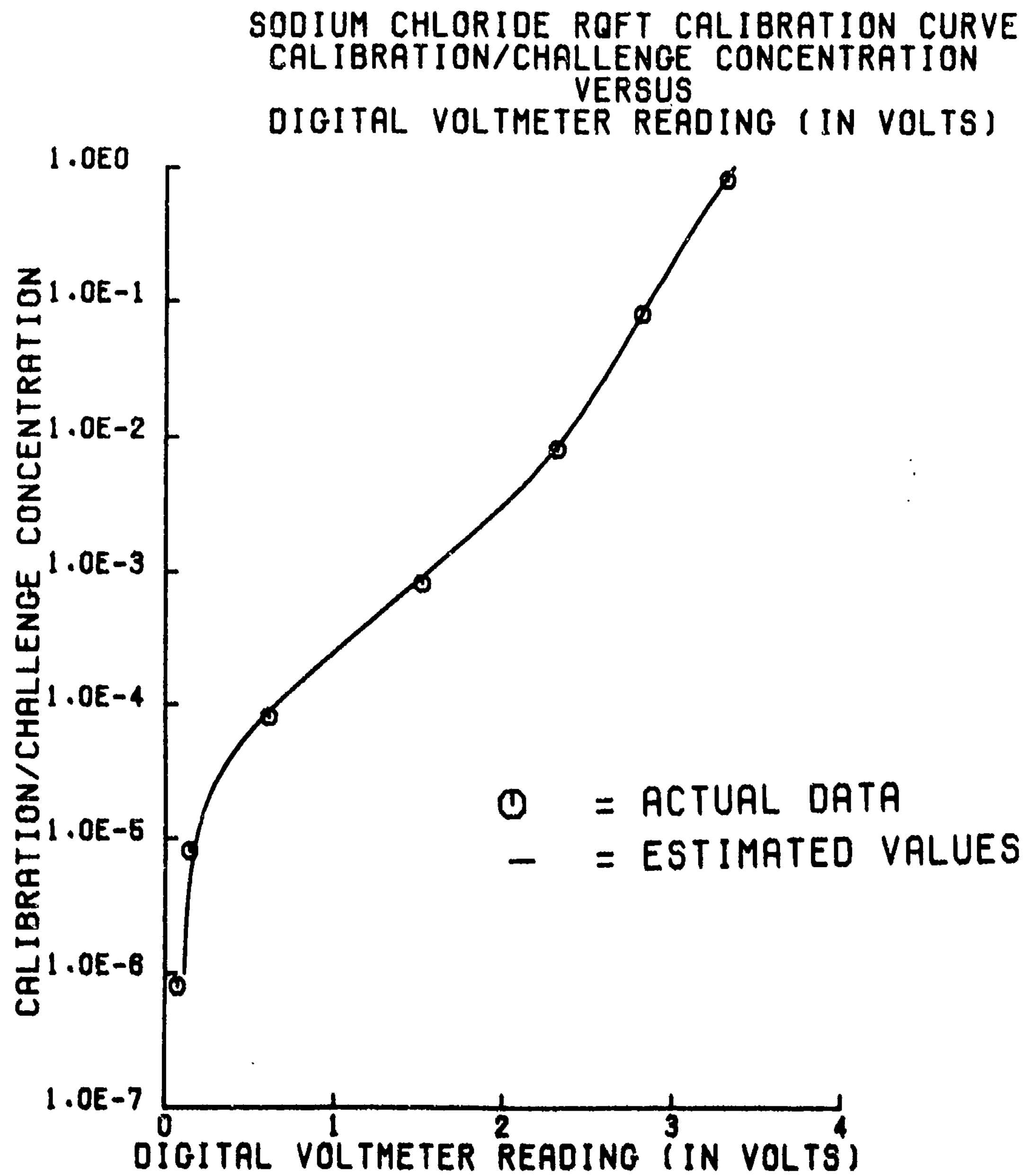

Figure 19. Computer-generated least squares curve fit plot (semilogarithmic) of the data presented in Table 7.

From the information in Table 8, the polynomial curve fit equation is:

$$
\begin{aligned}
y = {} & (-4.17904 \times 10^{-5}) + (-7.31487 \times 10^{-5})e^{x} + (1.25863 \times 10^{-4}(e^{x})^{2} + \\
& (-2.68095 \times 10^{-5})(e^{x})^{3} + (3.80138 \times 10^{-6})(e^{x})^{4} + \\
& (-1.71541 \times 10^{-7})(e^{x})^{5} + (3.88406 \times 10^{-9})(e^{x})^{6} \qquad (17)
\end{aligned}
$$

The residuals were calculated to measure the "goodness of fit" for the polynomial curve fit Equation 17. Since the RQFT data points are fully parameterized by Equation 17, the residuals and sum of the square residuals should be exactly zero. However, these values are not exactly equal to zero because of computer calculation round-off errors. The computer program made these calculations by substituting the set of sodium chloride calibration/challenge concentration (Y-coordinate values of Table 7) values into the polynomial curve fit Equation 17; the corresponding calculated Y values are called the Y-estimated values. One can readily observe that the sum of the square residuals is 2.80811×10^{-15}, a very small number indeed. Interestingly, the worst-case residual occurs for the 10^{-6} sodium chloride calibration standard; this finding implies that the accuracy of predicting a particular exercise mask leakage concentration will not be in error by more than 0.433% [$(0.100433 \times 10^{-5} - 0.100000 \times 10^{-5})/(0.100000 \times 10^{-5}) = 0.00433 \times 100$]. The magnitude of this error is representative of that found for several sets of calibration data that have been analyzed.

The following explanation is the key to understanding how a best fit polynomial curve (relating sodium chloride calibration/challenge concentration to a digital voltmeter response) can be used to calculate a PF. Two concepts are involved in the analysis.

First: the Y-axis is, in reality, an exact scale for the time-averaged mask leakage penetration (concentration). When the user calibrates the RQFT instrument, the strip-chart recorder displays (on its vertical or Y-axis) the PMT's response for a known diluted sodium chloride concentration sample. It is important to recognize that the response for the diluted concentration is equivalent to that which would be measured if one were to evaluate the fit of a mask with the 10^{0} sodium chloride challenge concentration, and have the mask fit be perfect, except for a "calibrated" leak that would permit a corresponding known diluted concentration of the 10^{0} challenge to penetrate the mask. The essence of the polynomial curve fit equation is that it permits "interpolation" between the responses for adjacent sodium chloride calibration concentrations.

Second: the integrator count--the source of data used to calculate a mask leakage penetration (concentration)--is, in reality, a time-averaged voltage response. This fact can be derived through the following analyses:

a. Integrator sensitivity is 1000 counts-per-volt•sec.

b. Each exercise is performed for a predetermined length of time; for example, 10 sec.

c. The integrator count (IC) value recorded for a particular exercise is actually the time-averaged area under the strip-chart recorder response (refer to Figs. 8 and 11).

Therefore,

$$IC\ (\text{counts}) = (1000\ \text{counts/volt}\cdot\text{sec})\cdot(\text{time in sec})(\overline{V}\ \text{volts}) \tag{18}$$

or, rearranging Equation 18 yields

$$\overline{V}\ \text{volts} = \frac{(IC\ \text{counts})(\text{volt}\cdot\text{sec})}{(1000\ \text{counts})(\text{time in sec})} \tag{19}$$

Thus,

$$\overline{V}\ \text{volts} = \frac{IC}{(1000)(\text{time in sec})} \tag{20}$$

in which $\overline{V}$ volts is the time-averaged voltage for a particular exercise.

The computer program, written to accept the integrator exercise count data and the time duration for each exercise, calculates corresponding exercise time-averaged voltages. Each time-averaged voltage is substituted into the polynomial curve fit Equation 17, and a corresponding mask leakage penetration (concentration) is calculated. The final set of calculations performed by the program are the individual exercise PF's, an arithmetic average PF, and a time-weighted average PF. Equation 5 is used to calculate individual PF's, and Equations 3 and 4 are used to calculate the average PF's. The results of the data in Tables 7 and 8 are given in Table 9.

Discussion of the Computer Programs Used to Process the USAFSAM Sodium Chloride RQFT Integrator Data

Two computer programs are used to process the integrator exercise data. The first and primary program is called NACLRQFT.FTN; the second, NACLGRAPH.FTN.

The purpose of NACLRQFT.FTN is to use the RQFT information collected on the RQFT data sheet (Fig. 16) and calculate a set of PF's. The results of this program are stored on three disk files:

1. DATA.XXX contains the initial calibration data, the test identification data, the time period for each exercise, and a listing of the exercises performed and their associated integrator count values.

2. CALCX.XXX contains the polynomial curve fit equation coefficients, the calculated residuals, the sum of the square residuals, a composite listing of the identification data, the exercises performed and their corresponding PF's, and the average PF's.

3. GRPHX.XXX contains an array of 401 X-axis values and 401 Y-axis values. These values were generated using the polynomial curve fit Equation 15. This array is used by the NACLGRAPH.FTN program to generate a CALCOMP calibration curve for the sodium chloride RQFT calibration data.

TABLE 9. PROTECTION FACTOR CALCULATIONS FOR THE DATA CONTAINED IN TABLE 7

SUBJECT NAME: Captain Edward S. Kolesar, Jr.

TYPE OF MASK: USA: M17 - Medium (no glasses)

DATE TESTED: 9 April 1980

TIME TESTED: 1330 hours

EXERCISE INTEGRATOR COUNT DATA

Exercise	Integrator count	Time period [sec]	Protection factor
Normal breathing straight ahead	3904	10	1.8E+04
Deep breathing straight ahead	4751	10	1.3E+04
Talking	4628	10	1.3E+04
Side-to-side head movements (deep breathing)	3976	10	1.7E+04
Up-and-down head movements (deep breathing)	4016	10	1.7E+04
Facial grimacing	4937	10	1.2E+04

Overall arithmetic average protection factor (PF) for all categories of exercises actually performed = 1.5E+04.

Overall time-weighted average protection factor (PF) for all categories of exercises actually performed = 1.5E+04.

The NACLGRAPH.FTN program has been written as a separate program because the USAFSAM PDP-11/70 CALCOMP plotter is an off-line device. That is, NACLGRAPH.FTN uses the GRPHX.XXX disk file as input data and sequences through the CALCOMP plot subroutine library files, and produces a user-named output disk file (for example, PLOT.SCD). The NACLGRAPH.FTN-generated output file is then transferred to a magnetic tape by one of the computer-room operators. The magnetic tape is then mounted on the CALCOMP terminal and the plot is generated [95].

Each of the programs discussed in this section is documented with comments that define the variables and explain the operations performed. Therefore, a line-by-line analysis of the code will not be done. For the interested reader, however, the following information is available in eight appendixes (A - H)

Appendix A: NACLRQFT.FTN Fortran listing

Appendix B: DATA.XXXX file contents for data in Table 7

Appendix C: CALCX.XXX file contents for information in Tables 8 and 9

Appendix D: GRPHX.XXX file contents for use with NACLGRAPH.FTN program

Appendix E: NACLGRAPH.FTN Fortran listing

Appendix F: CALCOMP generated plot (semilogarithmic) of the GRPHX.XXX data.

Appendix G: User's guide for the NACLRQFT.FTN computer program

Appendix H: User's guide for the NACLGRAPH.FTN computer program

REFERENCES

1. NATO Standardization Agreement (STANAG), First Draft STANAG 3864 AMD. The measurement of protection provided to the respiratory tract and eyes against NBC agents in particulate, aerosol and vapour form. MAS (AIR) (79) (68), 29 March 1979.

2. Hounam, R. F., D. J. Morgan, D. T. O'Connor, and R. J. Sherwood. The evaluation of protection provided by respirators. Ann Occup Hyg 7:353 (1964).

3. British Standard (BS) 2091. Specifications for respirators for protection against harmful dusts and gases. British Standards Institution, British Standards House, London, England (1969).

4. Letts, H. J. R. The limitations of gas masks as means of protection against occupational hazards. Design and use of respirators, p. 119. (Ed. by C. N. Davies) Oxford: Pergamon Press, 1961.

5. Testing Memorandum Number 6. Examination, test, and evaluation of dust respirators. Ministry of Fuel and Power, United Kingdom (1956).

6. Porton Specification 621C. Specification for the construction and performance of dust respirators. United Kingdom Ministry of Defence, CDEE, Porton Down, England (1957).

7. Porton Specification 1632A. Photo-electric sodium flame particulate test apparatus number two for respirator containers and small air filters. United Kingdom Ministry of Defence, CDEE, Porton Down, England (1959).

8. Hounam, R. F., and M. Walsh. A respirator testing unit based on a flame photometer. AERE HP Gen. 43, United Kingdom Atomic Energy Authority, Harwell, England (1964).

9. Vokes Ltd. Development Office Report No. 295. Sodium flame test rig. Guilford, England (February 21, 1965).

10. Dorman, R. G. Porton Note No. 349. The sodium flame test for respirator canisters. United Kingdom Ministry of Defence, CDEE, Porton Down, England (May 1966).

11. British Standard (BS) 4400. Method for sodium chloride particulate test for respirator filters. British Standards Institution, British Standards House, London, England (1969).

12. Minutes of the Respirator Quantitative Fit Testing Seminar. Sponsored by the Los Alamos Scientific Laboratory (LASL), Los Alamos, New Mexico, 8-9 March 1977.

13. Griffin, O. G., and D. J. Longson. The hazard due to inward leakage of gas into a full face mask. Ann Occup Hyg 13:147 (1970).

14. Hyatt, E. C., J. A. Pritchard, and C. P. Richards. Respirator efficiency measurement using quantitative DOP man tests. Amer Ind Hyg Assoc J 33:635 (1972).

15. Adley, F. E., and R. J. Uhle. Protection factors of self-contained compressed-air breathing apparatus. Amer Ind Hyg Assoc J 30:355 (1969).

16. White, J. M., and R. J. Beal. The measurement of leakage of respirators. Amer Ind Hyg Assoc J 27:239 (1966).

17. Burgess, W. A., and P. C. Reist. Supply rates for powered air-purifying respirators. Amer Ind Hyg Assoc J 30:1 (1969).

18. Adley, F. E., and D. E. Wisehart. Methods for performance testing of respiratory protective equipment. Amer Ind Hyg Assoc J 23:251 (1962).

19. Burgess, W. A., L. Silverman, and F. Stein. A new technique for evaluating respirator performance. Amer Ind Hyg Assoc J 22:422 (1961).

20. Packard, L. H., H. L. Brady, and O. F. Schuum. Quantitative fit testing of personnel utilizing a mouthpiece respirator. Amer Ind Hyg Assoc J 39:723 (1978).

21. Lowry, P. L., L. D. Wheat, and J. M. Bustos. Quantitative fit-test method for powered air-purifying respirators. Amer Ind Hyg Assoc J 40:291 (1979).

22. Burgess, W. A., and W. C. Hinds. Performance and acceptance of respirator facial seals. Ergonomics 13:455 (1970).

23. De Steiguer, D., E. B. McFadden, M. S. Pinski, and J. R. Bannister. The use of n-pentane as a tracer gas for the quantitative evaluation of aircrew protective breathing equipment. Proceedings of the Fourteenth Annual SAFE Symposium, pp. 15-19, September 1976.

24. De Steiguer, D., M. S. Pinski, J. R. Bannister, and E. B. McFadden. The objective evaluation of aircrew protective breathing equipment: II. Fullface masks and hoods. Proceedings of the Fourteenth Annual SAFE Symposium, pp. 10-12, September 1976.

25. Cyr, R. R., and D. W. Watkins. Facepiece-to-face leakage evaluation using a helium leak detection method. J Vac Sci Tech 12:419 (1975).

26. Williams, F. T. Photometric measurement of respirator fit test protection factors and their interpretation, use, and meaning. Technical Note 108-0008. Dynatech Frontier Corporation, Albuquerque, New Mexico, November 18, 1978.

27. Minutes of the ASTM Committee, E-34.14 Task Group, Occupational Health and Safety, 27-28 February 1979, Department of Labor, Occupational Safety and Health Administration, Constitution Avenue, Washington, D.C.

28. Lowry, P. L., C. F. Richards, L. A. Geoffrion, S. K. Yasuda, L. D. Wheat, J. M. Bustos, and D. D. Douglas. Respirator studies for the National Institute for Occupational Safety and Health. Progress report LA-7317-PR, Los Alamos Scientific Laboratory, Los Alamos, New Mexico (January 1 - December 31, 1977).

29. Hyatt, E. C., J. A. Pritchard, B. J. Held, D. A. Bevis, T. O. Davis, L. A. Geoffrion, A. L. Hack, P. L. Lowry, T. O. Moore, C. P. Richards, and L. D. Wheat. Respiratory studies for the National Institute for Occupational Safety and Health. Progress report LA-5620-PR, Los Alamos Scientific Laboratory, Los Alamos, New Mexico (July 1, 1972 - June 3, 1973).

30. Hyatt, E. C., J. A. Pritchard, C. P. Richards, L. A. Geoffrion, and I. K. Kressen. Respirator research and development related to quality control (LASL Project R-037). Progress report LA-4908-PR, Los Alamos Scientific Laboratory, Los Alamos, New Mexico (July 1 - September 30, 1971).

31. Jones, R. E. Quantitative measurement of face seal leakage and related contributory factors. Report NA-68-383, Los Angeles Division of the North American Rockwell Corporation (1968).

32. Watson, H. A., P. M. Gussey, and A. J. Beckert. Evaluation of chemical-cartridge respirator face fit. Report of investigations: 7431. United States Department of the Interior, Bureau of Mines, Washington, D.C. (1970).

33. Sodium chloride test system instruction manual. Internal report (not published), United States Air Force School of Aerospace Medicine, Crew Protection Branch, Brooks Air Force Base, Texas (current revision, 25 January 1979).

34. Pritchard, J. A. A guide to industrial respiratory protection. United States Department of Health, Education and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Cincinnati, Ohio (NIOSH Publication 76-189), June 1976.

35. Pasternack, A. The model 80 face mask fit-tester. Draeger Review 41:32 (1978).

36. Douglas, D. D., W. Revior, J. A. Pritchard, A. L. Hack, L. A. Geoffrion, T. O. Davis, P. L. Lowry, C. P. Richards, L. D. Wheat, J. M. Bustos, and P. R. Hesch. Respirator studies for the National Institute for Occupational Safety and Health. Progress report LA-6386-PR, Los Alamos Scientific Laboratory, Los Alamos, New Mexico (July 1, 1974 - June 30, 1975).

37. Hyatt, E. C. Respirator protection factors. Informal report LA-6084-MS, Los Alamos Scientific Laboratory, Los Alamos, New Mexico (January 1976).

38. Hyatt, E. C., J. A. Pritchard, L. A. Geoffrion, and C. P. Richards. Respirator performance measurement using quantitative sodium chloride aerosol man tests. Technical report LA-DC-13306, Los Alamos Scientific Laboratory, Los Alamos, New Mexico (May 1972).

39. Griffin, O. G., and D. J. Longson. Influence of facemask design on operational performance. Second Conference on Portable Life Support Systems, National Aeronautics and Space Administration, NASA SP-302, Ames Research Center, Moffett Field, California, May 11-13, 1971.

40. Hounam, R. F. A method for evaluating the protection afforded when wearing a respirator. Report AERE-R 4125, Atomic Energy Research Establishment, Harwell, England (1962).

41. Leigh, J. D. Quantitative respirator man-testing and anthropometric survey. RFP-2358, Dow Chemical Company, Rocky Flats Division, Golden, Colorado (1975).

42. Field test method for fitting respirators, National Safety News 100:41 (1969).

43. Hammond, S. E., and J. E. Hill. Rocky Flats respirator-fitting program. Dow Chemical Company, Rocky Flats Division, Golden, Colorado (1966).

44. Sedlacek, M. Error analysis of voltage integration by an electronic analog integrator in the time domain. Slaboproudy Obz (Czechoslovakia) 40:57 (1979).

45. Davies, A., and J. C. M. Wise. True integrator with automatic reset. Med Biol Engr Comput 16:573 (1978).

46. Bershadskii, I. G. Four-channel electronic integrator. Trans Biomed Eng 5:59 (1971).

47. Franklin, J. Electronic building bricks. XVIII. The integrator. Wireless World 77:596 (1971).

48. Drummond, G. B., and P. C. Goodenough. Automatic correction for drift in an integrator for phasic signals. Med Biol Engr Comput 15:688 (1977).

49. Tang, P. A., K. G. McNaughton, and T. A. Black. Precision electronic integrator for environmental measurements. Trans Am Soc Agric Eng 19:550 (1976).

50. Zappe, H. H., and R. S. Warren. Digitize analog curves with an integrator. Elec Des 20:66 (1972).

51. Yee, P. Designing a precision integrator with high speed mode controls. Elec Des News 16:34 (1971).

52. Atkins, A. R. A simple recorder integrator using a unijunction transistor. Elec Eng 28:440 (1967).

53. Effenberger, J. A., and R. Steele. A transistorized integrator. Elec Eng 26:230 (1965).

54. Whittaker, A. E. Long-term integrator uses digital techniques. Elec Eng 36:13 (1975).

55. Bulmer, G. J. High input impedance integrator. Wireless World 83·56 (1977).

56. Clayton, G. B. Operational amplifiers. London: Newnes-Butterworths Co Ltd, 1979.

57. Klement, C. Voltage-to-frequency converter constructed with few components is accurate to 0.2 percent. Elec Des 13:124 (1973).

58. Paul, R. J. A., and H. B. Gatland. The design and performance of a generalized electronic integrator. Proc IEEE 114:1193 (1967).

59. Demas, J. N. A digital integrator with a memory. Chem Instrum 5:283 (1973).

60. Klatt, L. N., and P. W. Carr. An inexpensive digital integrator for gas chromatography. Chem Instrum 3:327 (1972).

61. Pareles, S. R. Low-cost integrator with digital character. Anal Chem 45:998 (1973).

62. Bentz, A. J., J. R. Sandifer, and R. P. Buck. Wide-band, precision, DC-coupled lock-in detector and gated integrator for electrochemical measurements. Anal Chem 46:543 (1974).

63. Kendall, D. R. Versatile low cost laboratory integrator. Anal Chem 44:1109 (1972).

64. Malmstadt, H. V., and C. G. Enke. Electronics for Scientists. New York: W. A. Benjamin, 1963.

65. Bertram, F., J. E. Taphhorn, W. B. Robbins, E. J. Younginger, and J. A. Caruso. High-conversion-rate electronic integrator with digital readout for flameless atomic absorption spectrometry. Anal Chem 48:2271 (1976).

66. Grant, D. Applications of the AD537 IC voltage-to-frequency converter. Application Note E478A. Analog Devices Inc, Norwood, MA (May 1979).

67. Analog Devices 1979 Short Form Catalog. Electronic products for precision measurement and control. Analog Devices Inc., Norwood, MA (1979).

68. Pease, R. A. Voltage-to-frequency converters. Bulletin AN-1. Teledyne Philbrick Corp, Dedham, MA (Jan 1979).

69. Teledyne Philbrick Technical Staff. Need a 1 kHz full-scale V-F? Bulletin AN-2. Teledyne Philbrick Corp, Dedham, MA (Jan 1974).

70. Teledyne Philbrick Technical Staff. V-F's as long-term integrators. Bulletin AN-9. Teledyne Philbrick Corp, Dedham, MA (Jan 1974).

71. Goodenough, F. Solve your measurement problems with V/F and F/V converters. Bulletin AN-20. Teledyne Philbrick Corp, Dedham, MA (Sep 1975).

72. Teledyne Philbrick Technical Staff. How to specify and test V/F and F/V converters. Bulletin AN-22. Teledyne Philbrick Corp, Dedham, MA (Apr 1976).

73. Goodenough, F. Modular V/F's and F/V's: Simple solutions to everyday conversion problems. Bulletin AN-32. Teledyne Philbrick Corp, Dedham, MA (May 1977).

74. Precision Monolithics Incorporated, 1979 Full Line Catalog, Santa Clara, CA (1979).

75. Motorola Semiconductor Products Incorporated, McMOS Integrated Circuits Data Book, Phoenix, AZ (1979).

76. Texas Instruments Incorporated, The TTL Data Book for Design Engineers, Dallas, TX (1973).

77. Motorola Semiconductor Products Incorporated, Motorola Semiconductor Master Selection Guide and Catalog, Phoenix, AZ (1979).

78. Analog Devices Incorporated, Data Acquisition Products Catalog, Norwood, MA (1978).

79. Motorola Semiconductor products incorporated, McMOS Idea Book, Phoenix, AZ (1979).

80. Motorola Semiconductor Products Incorporated, McMOS Integrated Circuits from Motorola - MC14000 and MC14500 Series Complimentary MOS, Phoenix, AZ (1974).

81. Motorola Semiconductor Products Incorporated, MC14566 McMOS Industrial Time Base Generator Data Sheet, Phoenix, AZ (1975).

82. Dialight, Readout Displays Product Selector Guide, February 1980, Brooklyn, NY.

83. Hartree, D. R. Numerical Analysis. Oxford: University Press, 1952.

84. Householder, A. S. Principles of Numerical Analysis. New York: McGraw-Hill, 1953.

85. Milne, W. E. Numerical Calculus. New Jersey: Princeton University Press, 1949.

86. Salvadori, M. G., and M. L. Baron. Numerical Methods in Engineering. New York: Prentice-Hall, 1952.

87. Scarborough, J. B. Numerical Mathematical Analysis. Baltimore, MD: University Press, 1950.

88. Aitken, A. C. On interpolation by iteration of proportional parts without the use of differences. Edinburgh Mathematical Society Proceedings, Ser 2, Vol 3:56 (1932).

89. Guest, P. G. Note on the fitting of polynomials to equally-spaced observations. J Mathematics and Physics 32:68 (1953).

90. Kincaid, W. M. Solution of equations by interpolation. Ann Mathematical Statistics 19:207 (1948).

91. Lanczos, C. Trigonometric interpolation of empirical and analytical functions. J Mathematics and Physics 17:123 (1938).

92. Neville, E. H. Iterative interpolation. Indian Mathematical Soc J (Madras) 20:87 (1933).

93. Nielsen, K. L., and L. Goldstein. An algorithm for least squares. J Mathematics and Physics 26:120 (1947).

94. Franklin, P. Methods of Advanced Calculus. New York: McGraw-Hill, 1944.

95. Lozano, P. A. General Strip Chart Plotting Routine. SAM-TR-78-5. USAF School of Aerospace Medicine, Aerospace Medical Division (AFSC), Brooks AFB, TX (1978).

96. Gerald, C. F. Applied Numerical Analysis. Reading, MA: Addison-Wesley, 1973.

APPENDIX A:

NACLRQFT.FTN Fortran Listing

--APPENDIX A--

```
C
C     THIS PROGRAM CALCULATES PROTECTION FACTORS FOR DATA COLLECTED ON
C     THE USAFSAM/VNL SODIUM CHLORIDE RQFT INSTRUMENT.
C
C     CALCULATIONS ARE BASED ON INTEGRATING THE PHOTOMULTIPLIER
C     TUBE'S OUTPUT OVER A VARIABLE TIME PERIOD (10-20 SECONDS) FOR
C     EACH EXERCISE OF THE RQFT PROTOCOL.  SINCE THE INTEGRATOR'S
C     SENSITIVITY IS 1000 COUNTS PER (VOLT-SECOND), AND THE TIME PERIOD
C     FOR EACH EXERCISE IS VARIABLE (10-20 SECONDS), A SCALED OR
C     'AVERAGE' VOLTAGE FOR THE PHOTOMULTIPLIER OUTPUT CAN BE
C     CALCULATED BY THE FOLLOWING RELATIONSHIP:
C
C            APTVO=(IC)*(1/IS)*(1/VTPEE)
C
C     WHERE, APTVO=AVERAGE PHOTOMULTIPLIER TUBE VOLTAGE OUTPUT
C
C               IC=INTEGRATOR COUNT
C
C               IS=INTEGRATOR SENSITIVITY
C
C            VTPEE=VARIABLE TIME PERIOD FOR EACH EXERCISE
C
C     NEXT, A LEAST-SQUARES CURVE FITTING METHOD IS USED TO GENERATE A
C     POLYNOMIAL FUNCTION OF THE FORM:  Y=F(X).  THE DATA USED TO
C     GENERATE THIS FUNCTION ARE THE ORDERED PAIRS OF VALUES OF THE FORM
C     (X,Y), TABULATED WHEN CALIBRATING THE RQFT INSTRUMENT WITH THE
C     SODIUM CHLORIDE CALIBRATION STANDARDS.  IN THIS CASE:
C
C           X=PHOTOMULTIPLIER DETECTOR TUBE VOLTAGE OUTPUT (IN VOLTS)
C
C           Y=SODIUM CHLORIDE CALIBRATION STANDARD CONCENTRATION
C
C     THE RESULT OF THE CURVE FITTING PROCEDURE WILL BE THE CAPABILITY
C     TO DIRECTLY CALCULATE THE MASK LEAK CONCENTRATION FOR AN EXERCISE.
C     THIS IS SO BECAUSE THE POLYNOMIAL CURVE FITTING RELATIONSHIP OF
C     THE FORM: Y=F(X), DIRECTLY RELATES THE PHOTOMULTIPLIER TUBE'S
C     AVERAGE OUTPUT VOLTAGE TO CONCENTRATION (THAT IS, THE INTEGRATED
C     COUNT IS DIRECTLY RELATED TO MASK LEAKAGE CONCENTRATION FOR A
C     PARTICULAR EXERCISE).
C
C     THUS, FOR A PARTICULAR EXERCISE, A MASK LEAKAGE CONCENTRATION
C     IS CALCULATED BY SUBSTITUTING THE 'ADJUSTED' INTEGRATOR COUNT,
C     (THAT IS, THE APTVO VALUE), INTO THE POLYNOMIAL CURVE FITTING
C     FUNCTION.
C
C     FINALLY, A MASK LEAK CONCENTRATION IS CONVERTED TO A PROTECTION
C     FACTOR BY THE FOLLOWING RELATIONSHIP:
C
C            PF=(CC)/(ML)
C
C     WHERE, PF=PROTECTION FACTOR
C
C            CC=CHALLENGE CONCENTRATION (FOR THIS SYSTEM, 10 TO THE
C                                        ZERO OR 1.0)
C
C            ML=MASK LEAK CONCENTRATION FOR A PARTICULAR EXERCISE
C
```

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--APPENDIX A--

```
C     SINCE THE LEAST-SQUARES CURVE FITTING PROCEDURE IS THE KEY TO
C     THIS METHOD OF PROCESSING THE RQFT DATA, THE FOLLOWING COMMENTS
C     WILL DESCRIBE ITS IMPLEMENTATION IN THE PROGRAM.
C
C     THIS IS A PROGRAM WHICH UTILIZES A LEAST-SQUARES METHOD OF
C     APPROXIMATION TO DO CURVE FITTING.
C
C     THIS PROGRAM WILL TAKE A SET OF (N) NUMBER OF DATA POINTS AND
C     WILL FIT A POLYNOMIAL [UP TO DEGREE (N-1)] TO THE SET OF POINTS.
C
C     THIS PROGRAM DETERMINES THE COEFFICIENTS OF THE POLYNOMIAL BY
C     SOLVING A SYSTEM OF NORMAL EQUATIONS WHICH ARE DERIVED BY
C     CONSIDERING SOME QUANTITY (Y) AS A POLYNOMIAL FUNCTION OF ANOTHER
C     QUANTITY (X).
C
C     TO FIND THE BEST FITTING CURVE FOR A GIVEN SET OF DATA, THE
C     PROGRAM USER IS ONLY REQUIRED TO ENTER THE OBSERVED DATA POINTS
C     AND THE DEGREE OF THE POLYNOMIAL APPROXIMATION.
C
C     THE FIRST PART OF THE PROGRAM (STATEMENT LABEL NUMBERS: 5101 THRU
C     403) ACCEPTS THE DATA, STORES IT, AND ORGANIZES IT FOR USE IN
C     THE REMAINDER OF THE PROGRAM.
C
C     THE SECOND PART OF THE PROGRAM (STATEMENT LABEL NUMBERS: 400 THRU
C     500) ESTABLISH THE NORMAL EQUATIONS.  STATEMENT LABEL NUMBERS: 30
C     THRU 90 SOLVES THE NORMAL EQUATION SYSTEM.  IN THE FINAL SECTION
C     OF THE PROGRAM (STATEMENT NUMBERS: 16 THRU 11), THE ERRORS
C     (DIFFERENCES BETWEEN THE ACTUAL AND THE ESTIMATED VALUES) ARE
C     CALCULATED. IN ADDITION THE SUM OF THE SQUARE ERRORS IS
C     CALCULATED.  THE POLYNOMIAL FUNCTION PRODUCING THE SMALLEST
C     SUM OF SQUARE ERRORS YIELDS THE BEST CURVE FIT.  OBSERVATION
C     OF THE INDIVIDUAL ERRORS, ON THE OTHER HAND, GIVES A CLUE
C     AS TO THEIR RELATIVE DISTRIBUTION ABOUT THE BEST FIT
C     POLYNOMIAL CURVE.
C
C     THE USER IS GIVEN THE OPTION OF SELECTING A FUNCTIONAL
C     DEFINITION OF THE VARIABLE (X) SO THAT APPROXIMATIONS
C     CAN BE MADE TO CURVES THAT ARE NOT NECESSARILY
C     POLYNOMIALS IN (X).  FOR EXAMPLE:  Y=EXP(X) OR Y=1/(X).
C
C*********************************************************************
C*****                                                           *****
C*****  IF YOU HAVE ANY QUESTIONS CONCERNING THIS PROGRAM CALL   *****
C*****                                                           *****
C*****             CAPTAIN EDWARD S. KOLESAR, JR.                *****
C*****                                                           *****
C*****              USAFSAM/VNL   BROOKS AFB, TX                 *****
C*****                                                           *****
C*****       AUTOVON 240-2154   COMMERCIAL (512)536-2154         *****
C*****                                                           *****
C*********************************************************************
C
C
C     ARRAYS ARE DOUBLE PRECISION TO INSURE ACCURACY OF THE
C     CALCULATIONS.
C
      IMPLICIT INTEGER*4 (I-N)
```

--APPENDIX A--

```
      INTEGER FILTK
      DOUBLE PRECISION D(8,9),W(0:13),Z(0:13),B(8,9),E(8,9)
      DOUBLE PRECISION XAS(7),A(14),X(13),Y(13),THEORY,RESID,SRESD,XXX
      DOUBLE PRECISION DEL,XMIN,XMAX,XEST,BEGIN,XXMIN,XXMAS,XXAS(7)
      DOUBLE PRECISION PF(17),IC(17),ICTP(17),XXXX
      DIMENSION GRPH1(14),GRPH2(802),ICCBS(2)
      DIMENSION XX(401),YY(401)
      BYTE SECN(9)
      BYTE P(9),C(10),G(10)
      BYTE ANS,COMMEN,REP,COM
      BYTE SELECT(7),GROUP 1,GROUP 2
      BYTE YES,NO
      BYTE NAME(45),MASK(45),DATE(45),TIME(45)
      DATA SECN/'1','2','3','4','5','6','7','8','9'/
      YES='Y'
      NO='N'
C
C     ESTABLISH A FILE COUNTER AND DECLARE THE FILE NAMES.
C
 5101 FILTK=1
C
C     VARIABLES ARE SET EQUAL TO ZERO SO THAT ITERATIVE RUNS
C     ON THE SAME DATA CAN BE READILY PERFORMED.
C
      M=0
      NP=0
      ICCBS(1)=72*256+27
      ICCBS(2)=74*256+27
 4137 FORMAT(1H ,2A2)
      IC1=0.0
      IC2=0.0
      IC3=0.0
      IC4=0.0
      IC5=0.0
      IC6=0.0
      IC7=0.0
      IC8=0.0
      IC9=0.0
      IC10=0.0
      IC11=0.0
      IC12=0.0
      IC13=0.0
      IC14=0.0
      IC15=0.0
      IC16=0.0
      XC1=0.0
      XC2=0.0
      XC3=0.0
      XC4=0.0
      XC5=0.0
      XC6=0.0
      XC7=0.0
      XC8=0.0
      XC9=0.0
      XC10=0.0
      XC11=0.0
      XC12=0.0
```

```
      XC13=0.0
      XC14=0.0
      XC15=0.0
      XC16=0.0
      CALCPF=0.0
      XEST=0.0
      PFEST=0.0
      DEL=0.0
      THEORY=0.0
      RESID=0.0
      SRESD=0.0
      XXX=0.0
      BEGIN=0.0
      DO 9333 I=1,17
      IC(I)=0.0
      PF(I)=0.0
      ICTP(I)=0.0
 9333 CONTINUE
      DO 4153 I=1,7
      XAS(I)=0.0
      XXAS(I)=0.0
 4153 CONTINUE
C
C     THE FILES THAT HOLD VARIOUS SEGMENTS OF DATA ARE NAMED.
C
      DO 9334 I=1,13
      X(I)=0.0
      Y(I)=0.0
 9334 CONTINUE
      P(1)='D'
      P(2)='A'
      P(3)='T'
      P(4)='A'
      P(5)='.'
      P(9)=0
      C(1)='C'
      C(2)='A'
      C(3)='L'
      C(4)='C'
      C(5)=SECN(FILTK)
      C(6)='.'
      C(10)=0
      G(1)='G'
      G(2)='R'
      G(3)='P'
      G(4)='H'
      G(5)=SECN(FILTK)
      G(6)='.'
      G(10)=0
C
C     THE FILE CALLED DATA.XXX, CONTAINS THE SODIUM CHLORIDE
C     CALIBRATION STANDARD CONCENTRATION DATA TO BE FITTED
C     WITH THE POLYNOMIAL FUNCTION.
C
C     THE FILE CALLED CALCX.XXX, CONTAINS THE CALCULATED POLYNOMIAL
C     COEFFICIENTS, RESIDUALS, AND OTHER DESCRIPTIVE INFORMATION.
C
```

--APPENDIX A--

```
C     THE FILE CALLED GRPHX.XXX CONTAINS THE FOLLOWING ARRAYS:
C             [GRPH1]  SODIUM CHLORIDE CALIBRATION STANDARD
C                      CONCENTRATION DATA.
C             [GRPH2]  ESTIMATED VALUES DERIVED FROM EXERCISING
C                      THE POLYNOMIAL FUNCTION.
C
C     IF A PLOT OF THE ACTUAL DATA AND ESTIMATED VALUES IS DESIRED,
C     THE USER CAN USE THE FILE CALLED GRPHX.XXX FOR THIS PURPOSE.
C
C
C     NUMBER THE FILES SEQUENTIALLY SO THAT THEY CAN BE EASILY RETRIEVED
C     FOR PRINTING AND PLOTTING.
C
      TYPE 2006
 2006 FORMAT(1X,' '///)
 1002 FORMAT(1A1)
C
C     PROGRAM USER WILL UNIQUELY IDENTIFY EACH DATA FILE WITH A
C     SEQUENTIAL NUMBERING SYSTEM FOR EASE OF RECALL.
C
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      TYPE 2002
 2002 FORMAT(1X,'USER ATTENTION:  IN ORDER TO KEEP TRACK OF THE DATA'/
     C' SETS BEING ANALYZED, IT IS RECOMMENDED THAT THEY BE '/
     C' SEQUENTIALLY NUMBERED.'/)
      TYPE 306
      TYPE 2003
 2003 FORMAT(1X,'ENTER THE FOLLOWING:  001 FOR THE FIRST DATA SET; '/
     C' 002 FOR THE SECOND DATA SET; 003 FOR THE THIRD DATA SET, ETC.'/)
      TYPE 306
      TYPE 2004
 2004 FORMAT(1X,'ENTRY= ',$)
      ACCEPT 2005,P(6),P(7),P(8)
 2005 FORMAT(3A1)
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      TYPE 5100
 5100 FORMAT(1X,'USER ATTENTION:  IN ORDER TO KEEP TRACK OF THE'/
     C' POLYNOMIAL CURVE FITTING COEFFICIENTS AND RESIDUALS, IT'/
     C' IS RECOMMENDED THAT THEY BE SEQUENTIALLY NUMBERED.'/)
      TYPE 306
      TYPE 5200
 5200 FORMAT(1X,'ENTER THE FOLLOWING:  001 FOR THE FIRST RESIDUAL SET;'/
     C' 002 FOR THE SECOND RESIDUAL SET; 003 FOR THE THIRD, ETC.'/)
      TYPE 306
      TYPE 5300
 5300 FORMAT(1X,'ENTRY= ',$)
      ACCEPT 5400,C(7),C(8),C(9)
 5400 FORMAT(3A1)
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      TYPE 4001
 4001 FORMAT(1X,'USER ATTENTION:  IN ORDER TO KEEP TRACK OF THE GRAPH'/
     C' SETS BEING ANALYZED, IT IS RECOMMENDED THAT THEY BE'/
```

```
     C' SEQUENTIALLY NUMBERED'/)
      TYPE 306
      TYPE 4004
 4004 FORMAT(1X,'ENTER THE FOLLOWING:  001 FOR THE FIRST GRAPH SET;'/
     C' 002 FOR THE SECOND GRAPH SET; 003 FOR THE THIRD, ETC.'/)
      TYPE 306
      TYPE 2004
      ACCEPT 2005,G(7),G(8),G(9)
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      REP='N'
      GO TO 3081
 6000 FILTK=FILTK+1
      C(5)=SECN(FILTK)
      G(5)=SECN(FILTK)
      CLOSE(UNIT=3)
      CLOSE(UNIT=1)
      OPEN(UNIT=3,NAME=C,DISPOSE='SAVE',TYPE='NEW')
      OPEN(UNIT=1,NAME=G,DISPOSE='SAVE',TYPE='NEW')
      REWIND 2
      GO TO 6001
 3081 OPEN(UNIT=2,NAME=P,DISPOSE='SAVE',TYPE='NEW')
      OPEN(UNIT=3,NAME=C,DISPOSE='SAVE',TYPE='NEW')
      OPEN(UNIT=1,NAME=G,DISPOSE='SAVE',TYPE='NEW')
C
C     ENTER THE DATA TO BE PROCESSED.  IN THIS SITUATION, THE VOLTAGE
C     MEASUREMENTS ARE THE X-AXIS DATA AND THE SODIUM CHLORIDE
C     STANDARD CALIBRATION CONCENTRATIONS THE Y-AXIS DATA.
C
 1003 TYPE 1000
 1000 FORMAT(1X,'ENTER THE NUMBER OF SODIUM CHLORIDE CALIBRATION'/
     C' CONCENTRATION STANDARDS',/)
      TYPE 2004
      ACCEPT 2000,NP
 2000 FORMAT(I12)
C
C     OUTPUT THE INFORMATION USED TO PERFORM THE CALCULATIONS IN
C     THE DATAX.XXX FILE.
C
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      WRITE(2,2006)
 2007 FORMAT(1X,//////)
      WRITE(2,3001)NP
 3001 FORMAT(1X,24X,'THE NUMBER OF SODIUM CHLORIDE
     C CALIBRATION CONCENTRATION STANDARDS= ',I2)
      WRITE(2,2006)
      TYPE 3000
 3000 FORMAT(1X,'DEPRESS RETURN KEY AFTER ENTERING A VOLTAGE'/
     C' MEASUREMENT'//)
      TYPE 2006
C
C     THE FOLLOWING INFORMATION IS AVAILABLE FROM THE DATA SHEET
C     USED DURING AN ROPT EVALUATION.
C
```

--APPENDIX A--

```
      TYPE 4000
4000  FORMAT(1X,'ENTER THE DATA POINTS'/
     C' SAMPLE NUMBER        VOLTAGE                  SODIUM CHLORIDE'/
     C'                      MEASUREMENT              CALIBRATION'/
     C'                      IN VOLTS                 CONCENTRATION'/
     C'                      (X DATA)                 (Y DATA)'/)
      WRITE(2,3003)
3003  FORMAT(1X,24X,'SAMPLE NUMBER',18X,'VOLTAGE',23X,'SODIUM CHLORIDE')
      WRITE(2,3082)
3082  FORMAT(1X,24X,13X,18X,'MEASUREMENT',19X,'CALIBRATION')
      WRITE(2,3083)
3083  FORMAT(1X,24X,13X,18X,'(IN VOLTS)',20X,'CONCENTRATION')
      WRITE(2,3084)
3084  FORMAT(1X,24X,13X,18X,'( X DATA )',20X,'( Y DATA )'/)
      LINES=0
      DO 5001 I=1,NP
      TYPE 4500, I
4500  FORMAT(1H+,T7,1I2,T20,1H ,$)
      ACCEPT 5000, X(I)
      CALL CLEAR(LINES)
      TYPE 4501, I,X(I)
4501  FORMAT('+',T7,1I2,T21,1G13.6,'        ',$)
      ACCEPT 5000, Y(I)
      TYPE 306
5000  FORMAT(1G13.6)
      XAS(I)=X(I)
      XXAS(I)=X(I)
      WRITE(2,5002)I,X(I),Y(I)
5002  FORMAT(1X,29X,1I2,23X,1G13.6,19X,1G13.6)
5001  CONTINUE
C
C     ENTER THE DESCRIPTIVE INFORMATION CONCERNING THE SUBJECT, MASK,
C     DATE, AND TIME TESTED.
C
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
3077  TYPE 3085
3085  FORMAT(1X,'SUBJECT NAME:',2X,$)
      ACCEPT 3086,NAME
3086  FORMAT(45A1)
      TYPE 3087
3087  FORMAT(1X,'TYPE OF MASK:',2X,$)
      ACCEPT 3086,MASK
      TYPE 3088
3088  FORMAT(1X,'DATE TESTED:',2X,$)
      ACCEPT 3089,DATE
3089  FORMAT(45A1)
      TYPE 3090
3090  FORMAT(1X,'TIME TESTED:',2X,$)
      ACCEPT 3089,TIME
      TYPE 2006
3092  FORMAT(I2)
      TYPE 2006
C
C     ENTER THE INTEGRATION EXERCISE COUNT DATA FOR THE TEST PROTOCOL.
C
```

```
C
C     THIS INFORMATION IS AVAILABLE FROM THE DATA SHEET
C     USED DURING AN RQFT EVALUATION.
C
C
C     SELECT THE EXERCISE PROTOCOL.
C
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
 4139 TYPE 3127
 3127 FORMAT(1X,'THE USER IS FREE TO SELECT ONE OF TWO GROUPS OF'/
     C' EXERCISE PROTOCOLS.'//)
      TYPE 3128
 3128 FORMAT(1X,'THE [GROUP 1] EXERCISE PROTOCOL CONSISTS OF:'//
     C' [1]  NORMAL BREATHING STRAIGHT AHEAD'/
     C' [2]  DEEP BREATHING STRAIGHT AHEAD'/
     C' [3]  TALKING'/
     C' [4]  SIDE-TO-SIDE HEAD MOVEMENTS (DEEP BREATHING)'/
     C' [5]  UP-AND-DOWN HEAD MOVEMENTS  (DEEP BREATHING)'/
     C' [6]  FACIAL GRIMACING'///)
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      TYPE 3129
 3129 FORMAT(1X,'THE [GROUP 2] EXERCISE PROTOCOL CONSISTS OF:'//
     C' [1]  NORMAL BREATHING STRAIGHT AHEAD'/
     C' [2]  NORMAL BREATHING LEFT'/
     C' [3]  NORMAL BREATHING RIGHT'/
     C' [4]  NORMAL BREATHING DOWN'/
     C' [5]  NORMAL BREATHING UP'/
     C' [6]  DEEP BREATHING STRAIGHT AHEAD'/
     C' [7]  DEEP BREATHING LEFT'/
     C' [8]  DEEP BREATHING RIGHT')
      TYPE 3130
 3130 FORMAT(1X,'[9]  DEEP BREATHING DOWN'/
     C' [10] DEEP BREATHING UP'/
     C' [11] TALKING'/
     C' [12] FACIAL GRIMACING'/
     C' [13] SIDE-TO-SIDE HEAD MOVEMENTS (NORMAL BREATHING)'/
     C' [14] UP-AND-DOWN HEAD MOVEMENTS  (NORMAL BREATHING)'/
     C' [15] SIDE-TO-SIDE HEAD MOVEMENTS (DEEP BREATHING)'/
     C' [16] UP-AND-DOWN HEAD MOVEMENTS  (DEEP BREATHING)'//)
 4138 TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      TYPE 3131
 3131 FORMAT(1X,'TO SPECIFY THE EXERCISE PROTOCOL GROUP OF INTEREST,'/
     C' TYPE EITHER:  GROUP 1   OR   GROUP 2   ')
      TYPE 306
      TYPE 3199
 3199 FORMAT(1X,'ENTRY = ',$)
      ACCEPT 3122,SELECT
 3122 FORMAT(7A1)
      IF(SELECT(7).NE.'1'.AND.SELECT(7).NE.'2') GO TO 4138
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
```

```
      TYPE 2006
      TYPE 3021
3021 FORMAT(1X,'USER ATTENTION:  IF NO EXERCISE COUNT DATA WAS'/
    C' COLLECTED FOR A PARTICULAR EXERCISE, TYPE:  000001.  ALSO,'/
    C' FOR EACH TYPED EXERCISE COUNT DATA ENTRY, SIX DIGITS MUST')
      TYPE 3022
3022 FORMAT(1X,'BE TYPED, THAT IS, IF YOU HAVE A SIX DIGIT NUMBER,'/
    C' TYPE ALL SIX DIGITS.  IF YOU HAVE A FIVE DIGIT NUMBER, TYPE'/
    C' ONE LEADING ZERO AND THEN THE FIVE DIGITS.  IF YOU HAVE A')
      TYPE 3033
3033 FORMAT(' FOUR DIGIT NUMBER, TYPE TWO LEADING ZEROS AND THEN THE'/
    C' FOUR DIGITS, ETC.  SEVERAL EXAMPLES FOLLOW AS AN ILLUSTRATION')
      TYPE 3034
3034 FORMAT(1X,'FOR EXAMPLE:  COUNT DATA=743182   TYPED ENTRY=743182')
      TYPE 3035
3035 FORMAT(1X,'FOR EXAMPLE:  COUNT DATA=18726    TYPED ENTRY=018726')
      TYPE 3036
3036 FORMAT(1X,'FOR EXAMPLE:  COUNT DATA=6412     TYPED ENTRY=006412')
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      TYPE 3119
3119 FORMAT(1X,'DEPRESS THE RETURN KEY AFTER ENTERING AN'/
    C' INTEGRATOR COUNT'/)
      TYPE 2006
      TYPE 3037
3037 FORMAT(1X,'EXERCISE COUNT DATA:'/)
      TYPE 3038
3038 FORMAT(1X,'EXERCISE',29X,'INTEGRATOR',7X,'TIME PERIOD')
      TYPE 3126
3126 FORMAT(1X,40X,'COUNT',9X,'(IN SECONDS)'/)
      IF(SELECT(7) .EQ. '2') GO TO 3133
      TYPE 3039
3039 FORMAT(1X,'NORMAL BREATHING STRAIGHT AHEAD      ',$)
      ACCEPT 3040,IC1
      CALL CLEAR(LINES)
3040 FORMAT(I6)
      TYPE 3112,IC1
3112 FORMAT(1H+,'NORMAL BREATHING STRAIGHT AHEAD',T39,I6,T59,1H ,$)
      ACCEPT 3113,ICTP1
3113 FORMAT(I2)
      TYPE 3041
3041 FORMAT(1X,'DEEP BREATHING STRAIGHT AHEAD        ',$)
      ACCEPT 3040,IC2
      CALL CLEAR(LINES)
      TYPE 3114,IC2
3114 FORMAT(1H+,'DEEP BREATHING STRAIGHT AHEAD',T39,I6,T59,
    *1H ,$)
      ACCEPT 3113,ICTP2
      TYPE 3042
3042 FORMAT(1X,'TALKING                              ',$)
      ACCEPT 3040,IC3
      CALL CLEAR(LINES)
      TYPE 3115,IC3
3115 FORMAT(1H+,'TALKING',T39,I6,T59,1H ,$)
      ACCEPT 3113,ICTP3
      TYPE 3043
```

```
3043 FORMAT(1X,'SIDE-TO-SIDE HEAD MOVEMENTS'/
    C' (DEEP BREATHING)',20X,1H ,$)
     ACCEPT 3040,IC4
     CALL CLEAR(LINES)
     TYPE 3116,IC4
3116 FORMAT(1H+,'(DEEP BREATHING)',T39,I6,T59,1H ,$)
     ACCEPT 3113,ICTP4
     TYPE 3044
3044 FORMAT(1X,'UP-AND-DOWN HEAD MOVEMENTS'/
    C' (DEEP BREATHING)',20X,1H ,$)
     ACCEPT 3040,IC5
     CALL CLEAR(LINES)
     TYPE 3116,IC5
     ACCEPT 3113,ICTP5
     TYPE 3045
3045 FORMAT(1X,'FACIAL GRIMACING',20X,1H ,$)
     ACCEPT 3040,IC6
     CALL CLEAR(LINES)
     TYPE 3117,IC6
3117 FORMAT(1H+,'FACIAL GRIMACING',T39,I6,T59,1H ,$)
     ACCEPT 3113,ICTP6
     TYPE 2006
     TYPE 4137,ICCBS(1),ICCBS(2)
     TYPE 2006
     GO TO 3153
3133 CONTINUE
     TYPE 3039
     ACCEPT 3040,IC1
     CALL CLEAR(LINES)
     TYPE 3112,IC1
     ACCEPT 3113,ICTP1
     TYPE 3134
3134 FORMAT(1X,'NORMAL BREATHING LEFT                 ,$)
     ACCEPT 3040,IC2
     CALL CLEAR(LINES)
     TYPE 3135,IC2
3135 FORMAT(1H+,'NORMAL BREATHING LEFT',T39,I6,T59,1H ,$)
     ACCEPT 3113,ICTP2
     TYPE 3136
3136 FORMAT(1X,'NORMAL BREATHING RIGHT               ',$)
     ACCEPT 3040,IC3
     CALL CLEAR(LINES)
     TYPE 3137,IC3
3137 FORMAT(1H+,'NORMAL BREATHING RIGHT',T39,I6,T59,1H ,$)
     ACCEPT 3113,ICTP3
     TYPE 3138
3138 FORMAT(1X,'NORMAL BREATHING DOWN                ',$)
     ACCEPT 3040,IC4
     CALL CLEAR(LINES)
     TYPE 3139,IC4
3139 FORMAT(1H+,'NORMAL BREATHING DOWN',T39,I6,T59,1H ,$)
     ACCEPT 3113,ICTP4
     TYPE 3140
3140 FORMAT(1X,'NORMAL BREATHING UP                  ',$)
     ACCEPT 3040,IC5
     CALL CLEAR(LINES)
     TYPE 3141,IC5
```

```
3141 FORMAT(1H+,'NORMAL BREATHING UP',T39,I6,T59,1H ,$)
     ACCEPT 3113,ICTP5
     TYPE 3041
     ACCEPT 3040,IC6
     CALL CLEAR(LINES)
     TYPE 3114,IC6
     ACCEPT 3113,ICTP6
     TYPE 3142
3142 FORMAT(1X,'DEEP BREATHING LEFT                 ',$)
     ACCEPT 3040,IC7
     CALL CLEAR(LINES)
     TYPE 3143,IC7
3143 FORMAT(1H+,'DEEP BREATHING LEFT',T39,I6,T59,1H ,$)
     ACCEPT 3113,ICTP7
     TYPE 3144
3144 FORMAT(1X,'DEEP BREATHING RIGHT                ',$)
     ACCEPT 3040,IC8
     CALL CLEAR(LINES)
     TYPE 3145,IC8
3145 FORMAT(1H+,'DEEP BREATHING RIGHT',T39,I6,T59,1H ,$)
     ACCEPT 3113,ICTP8
     TYPE 3146
3146 FORMAT(1X,'DEEP BREATHING DOWN                 ',$)
     ACCEPT 3040,IC9
     CALL CLEAR(LINES)
     TYPE 3147,IC9
3147 FORMAT(1H+,'DEEP BREATHING DOWN',T39,I6,T59,1H ,$)
     ACCEPT 3113,ICTP9
     TYPE 3148
3148 FORMAT(1X,'DEEP BREATHING UP                   ',$)
     ACCEPT 3040,IC10
     CALL CLEAR(LINES)
     TYPE 3149,IC10
3149 FORMAT(1H+,'DEEP BREATHING UP',T39,I6,T59,1H ,$)
     ACCEPT 3113,ICTP10
     TYPE 3042
     ACCEPT 3040,IC11
     CALL CLEAR(LINES)
     TYPE 3115,IC11
     ACCEPT 3113,ICTP11
     TYPE 3045
     ACCEPT 3040,IC12
     CALL CLEAR(LINES)
     TYPE 3117,IC12
     ACCEPT 3113,ICTP12
     TYPE 3150
3150 FORMAT(1X,'SIDE-TO-SIDE HEAD MOVEMENTS'/
    C' (NORMAL BREATHING)                  ',$)
     ACCEPT 3040,IC13
     CALL CLEAR(LINES)
     TYPE 3151,IC13
3151 FORMAT(1H+,'(NORMAL BREATHING)',T39,I6,T59,1H ,$)
     ACCEPT 3113,ICTP13
     TYPE 3152
3152 FORMAT(1X,'UP-AND-DOWN HEAD MOVEMENTS'/
    C' (NORMAL BREATHING)                  ',$)
     ACCEPT 3040,IC14
```

```
      CALL CLEAR(LINES)
      TYPE 3151,IC14
      ACCEPT 3113,ICTP14
      TYPE 3043
      ACCEPT 3040,IC15
      CALL CLEAR(LINES)
      TYPE 3116,IC15
      ACCEPT 3113,ICTP15
      TYPE 3044
      ACCEPT 3040,IC16
      CALL CLEAR(LINES)
      TYPE 3116,IC16
      ACCEPT 3113,ICTP16
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
3153  TYPE 2006
      WRITE(2,2006)
      WRITE(2,3046)NAME
3046  FORMAT(6X,'SUBJECT NAME:',2X,45A1)
      WRITE(2,3047)MASK
3047  FORMAT(6X,'TYPE OF MASK:',2X,45A1)
      WRITE(2,3048)DATE
3048  FORMAT(6X,'DATE TESTED :',2X,45A1)
      WRITE(2,3049)TIME
3049  FORMAT(6X,'TIME TESTED :',2X,45A1)
      WRITE(2,2006)
      WRITE(2,9006)
9006  FORMAT(6X,'EXERCISE INTEGRATOR COUNT DATA:'/)
      WRITE(2,3094)
3094  FORMAT(6X,'EXERCISE',29X,'INTEGRATOR COUNT',7X,'TIME PERIOD')
      WRITE(2,3120)
3120  FORMAT(6X,8X,29X,16X,7X,'(IN SECONDS)',/)
      IF(SELECT(7) .EQ. '2') GO TO 3154
      XC1=IC1
      XC2=IC2
      XC3=IC3
      XC4=IC4
      XC5=IC5
      XC6=IC6
      IC(1)=XC1
      IC(2)=XC2
      IC(3)=XC3
      IC(4)=XC4
      IC(5)=XC5
      IC(6)=XC6
      ICTP(1)=ICTP1
      ICTP(2)=ICTP2
      ICTP(3)=ICTP3
      ICTP(4)=ICTP4
      ICTP(5)=ICTP5
      ICTP(6)=ICTP6
      WRITE(2,3051)IC1,ICTP1
3051  FORMAT(6X,'NORMAL BREATHING STRAIGHT AHEAD',11X,I6,17X,I2)
      WRITE(2,3052)IC2,ICTP2
      WRITE(2,3053)IC3,ICTP3
3052  FORMAT(6X,'DEEP BREATHING STRAIGHT AHEAD',13X,I6,17X,I2)
3053  FORMAT(6X,'TALKING',35X,I6,17X,I2)
```

```
      WRITE(2,3054)IC4,ICTP4
 3054 FORMAT(6X,'SIDE-TO-SIDE HEAD MOVEMENTS'/
     C'       (DEEP BREATHING)',26X,I6,17X,I2)
      WRITE(2,3055)IC5,ICTP5
 3055 FORMAT(6X,'UP-AND-DOWN HEAD MOVEMENTS'/
     C'       (DEEP BREATHING)',26X,I6,17X,I2)
      WRITE(2,3056)IC6,ICTP6
 3056 FORMAT(6X,'FACIAL GRIMACING',26X,I6,17X,I2//)
      GO TO 3155
 3154 CONTINUE
      XC1=IC1
      XC2=IC2
      XC3=IC3
      XC4=IC4
      XC5=IC5
      XC6=IC6
      XC7=IC7
      XC8=IC8
      XC9=IC9
      XC10=IC10
      XC11=IC11
      XC12=IC12
      XC13=IC13
      XC14=IC14
      XC15=IC15
      XC16=IC16
      IC(1)=XC1
      IC(2)=XC2
      IC(3)=XC3
      IC(4)=XC4
      IC(5)=XC5
      IC(6)=XC6
      IC(7)=XC7
      IC(8)=XC8
      IC(9)=XC9
      IC(10)=XC10
      IC(11)=XC11
      IC(12)=XC12
      IC(13)=XC13
      IC(14)=XC14
      IC(15)=XC15
      IC(16)=XC16
      ICTP(1)=ICTP1
      ICTP(2)=ICTP2
      ICTP(3)=ICTP3
      ICTP(4)=ICTP4
      ICTP(5)=ICTP5
      ICTP(6)=ICTP6
      ICTP(7)=ICTP7
      ICTP(8)=ICTP8
      ICTP(9)=ICTP9
      ICTP(10)=ICTP10
      ICTP(11)=ICTP11
      ICTP(12)=ICTP12
      ICTP(13)=ICTP13
      ICTP(14)=ICTP14
      ICTP(15)=ICTP15
```

```
      ICTP(16)=ICTP16
      WRITE(2,3051)IC1,ICTP1
      WRITE(2,3156)IC2,ICTP2
 3156 FORMAT(6X,'NORMAL BREATHING LEFT',21X,I6,17X,I2)
      WRITE(2,3157)IC3,ICTP3
 3157 FORMAT(6X,'NORMAL BREATHING RIGHT',20X,I6,17X,I2)
      WRITE (2,3158)IC4,ICTP4
 3158 FORMAT(6X,'NORMAL BREATHING DOWN',21X,I6,17X,I2)
 3159 FORMAT(6X,'NORMAL BREATHING UP',23X,I6,17X,I2)
      WRITE(2,3159)IC5,ICTP5
      WRITE(2,3052)IC6,ICTP6
      WRITE(2,3160)IC7,ICTP7
 3160 FORMAT(6X,'DEEP BREATHING LEFT',23X,I6,17X,I2)
      WRITE(2,3161)IC8,ICTP8
 3161 FORMAT(6X,'DEEP BREATHING RIGHT',22X,I6,17X,I2)
      WRITE(2,3162)IC9,ICTP9
 3162 FORMAT(6X,'DEEP BREATHING DOWN',23X,I6,17X,I2)
      WRITE(2,3163)IC10,ICTP10
 3163 FORMAT(6X,'DEEP BREATHING UP',25X,I6,17X,I2)
      WRITE(2,3053)IC11,ICTP11
      WRITE(2,3164)IC12,ICTP12
 3164 FORMAT(6X,'FACIAL GRIMACING',26X,I6,17X,I2)
      WRITE(2,3165)IC13,ICTP13
 3165 FORMAT(6X,'SIDE-TO-SIDE HEAD MOVEMENTS'/
     C'        (NORMAL BREATHING)',24X,I6,17X,I2)
      WRITE(2,3166)IC14,ICTP14
 3166 FORMAT(6X,'UP-AND-DOWN HEAD MOVEMENTS'/
     C'        (NORMAL BREATHING)',24X,I6,17X,I2)
      WRITE(2,3054)IC15,ICTP15
      WRITE(2,3055)IC16,ICTP16
 3155 REP='N'
 3888 IF(REP.EQ.NO) GO TO 3999
      GO TO 9983
C
C     CALCULATE THE AVERAGE PHOTOMULTIPLIER TUBE OUTPUT VOLTAGE FOR
C     EACH EXERCISE
C
 3999 CONTINUE
      IF(SELECT(7) .EQ. '2') GO TO 3167
      DO 3093 I=1,6
      IC(I)=IC(I)/(1000.0*ICTP(I))
 3093 CONTINUE
      GO TO 3168
 3167 CONTINUE
      DO 3169 I=1,16
      IC(I)=IC(I)/(1000.0*ICTP(I))
 3169 CONTINUE
 3168 CONTINUE
      END FILE 2
 9983 CONTINUE
      REWIND 2
 6001 READ(2,2006)
      READ(2,3001)NP
 3002 FORMAT(1X,52X,I2)
C
C     AFTER ALL PERTINENT INFORMATION IS ENTERED INTO THE DATA.XXX FILE,
C     THE FILE IS REWOUND AND THE POINTER MOVED TO READ THE DATA  NEEDED
```

--APPENDIX A--

```
C     TO CALCULATE THE LEAST-SQUARES POLYNOMIAL FUNCTION.
C
      READ(2,2006)
      READ(2,3003)
      READ(2,3082)
      READ(2,3083)
      READ(2,3084)
C
C     TO MAKE THE LEAST-SQUARES POLYNOMIAL CURVE FIT ROUTINE AS
C     FLEXIBLE AS POSSIBLE, THE USER CAN SELECT A VARIETY OF
C     FUNCTIONAL DEFINITIONS FOR THE VARIABLE (X).
C
 2013 TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      TYPE 2009
 2009 FORMAT(1X,'THE USER IS FREE TO SELECT ANY ONE OF THE FOLLOWING'/
     C' FUNCTIONAL DEFINITIONS OF THE VARIABLE  (X).'/)
      TYPE 306
      TYPE 2010
 2010 FORMAT(1X,'[1]  (X)'/
     C' [2]  1/(X)'/
     C' [3]  EXPONENTIAL (X)'/
     C' [4]  EXPONENTIAL (-X)'/
     C' [5]  EXPONENTIAL (1/X)'/
     C' [6]  EXPONENTIAL (-1/X)'/
     C' [7]  NATURAL LOG (X)'/
     C' [8]  LOG BASE TEN (X)'/
     C' [9]  SIN (X)'/)
      TYPE 306
      TYPE 2011
 2011 FORMAT(1X,'TO SPECIFY A FUNCTIONAL DEFINITION OF (X), SELECT'/
     C' THE CORRESPONDING NUMBER INSIDE THE BRACKETS'/)
      TYPE 306
      TYPE 2004
      ACCEPT 2012,IAX
 2012 FORMAT(1I1)
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      IF(IAX.GT.0.AND.IAX.LT.10) GO TO 2014
      GO TO 2013
C
C     DOUBLE PRECISION CALCULATIONS ARE MADE TO RESOLVE PROBLEMS
C     ENCOUNTERED WHEN DEALING WITH DATA THAT RANGES OVER SEVERAL
C     ORDERS OF MAGNITUDE.
C
C
C     THE FOLLOWING 'DO LOOP' CALCULATES AN EQUIVALENT VALUE
C     FOR THE (X) VARIABLES BASED ON THE SELECTED FUNCTIONAL
C     DEFINITION.
C
 2014 DO 300 I=1,NP
      K=I
      READ(2,5002)K,X(K),Y(K)
      IF(IAX.EQ.1) X(I)=X(I)
      IF(IAX.EQ.2) X(I)=1.0/X(I)
```

```
      IF(IAX.EQ.3) X(I)=DEXP(X(I))
      IF(IAX.EQ.8) X(I)=DLOG10(X(I))
      IF(IAX.EQ.7) X(I)=DLOG(X(I))
      IF(IAX.EQ.9) X(I)=DSIN(X(I))
      IF(IAX.EQ.4) X(I)=DEXP(-X(I))
      IF(IAX.EQ.5) X(I)=DEXP(1.0/X(I))
      IF(IAX.EQ.6) X(I)=DEXP(-1.0/X(I))
  300 CONTINUE
      IF(REP.EQ.YES) GO TO 9777
      GO TO 9888
 9777 READ(2,2006)
      READ(2,3046) NAME
      READ(2,3047) MASK
      READ(2,3048) DATE
      READ(2,3049) TIME
      READ(2,2006)
      READ(2,9006)
      READ(2,3094)
      READ(2,3120)
      IF(SELECT(7) .EQ. '2') GO TO 3170
      READ(2,3051) IC1,ICTP1
      READ(2,3052) IC2,ICTP2
      READ(2,3053) IC3,ICTP3
      READ(2,3054) IC4,ICTP4
      READ(2,3055) IC5,ICTP5
      READ(2,3056) IC6,ICTP6
      XC1=IC1
      XC2=IC2
      XC3=IC3
      XC4=IC4
      XC5=IC5
      XC6=IC6
      IC(1)=XC1
      IC(2)=XC2
      IC(3)=XC3
      IC(4)=XC4
      IC(5)=XC5
      IC(6)=XC6
      ICTP(1)=ICTP1
      ICTP(2)=ICTP2
      ICTP(3)=ICTP3
      ICTP(4)=ICTP4
      ICTP(5)=ICTP5
      ICTP(6)=ICTP6
      DO 9417 I=1,6
      IC(I)=IC(I)/(1000.0*ICTP(I))
 9417 CONTINUE
      GO TO 3171
 3170 READ(2,3051)IC1,ICTP1
      READ(2,3156)IC2,ICTP2
      READ(2,3157)IC3,ICTP3
      READ(2,3158)IC4,ICTP4
      READ(2,3159)IC5,ICTP5
      READ(2,3052)IC6,ICTP6
      READ(2,3160)IC7,ICTP7
      READ(2,3161)IC8,ICTP8
      READ(2,3162)IC9,ICTP9
```

--APPENDIX A--

```
READ(2,3163)IC10,ICTP10
READ(2,3053)IC11,ICTP11
READ(2,3164)IC12,ICTP12
READ(2,3165)IC13,ICTP13
READ(2,3166)IC14,ICTP14
READ(2,3054)IC15,ICTP15
READ(2,3055)IC16,ICTP16
XC1=IC1
XC2=IC2
XC3=IC3
XC4=IC4
XC5=IC5
XC6=IC6
XC7=IC7
XC8=IC8
XC9=IC9
XC10=IC10
XC11=IC11
XC12=IC12
XC13=IC13
XC14=IC14
XC15=IC15
XC16=IC16
ICTP(1)=ICTP1
ICTP(2)=ICTP2
ICTP(3)=ICTP3
ICTP(4)=ICTP4
ICTP(5)=ICTP5
ICTP(6)=ICTP6
ICTP(7)=ICTP7
ICTP(8)=ICTP8
ICTP(9)=ICTP9
ICTP(10)=ICTP10
ICTP(11)=ICTP11
ICTP(12)=ICTP12
ICTP(13)=ICTP13
ICTP(14)=ICTP14
ICTP(15)=ICTP15
ICTP(16)=ICTP16
IC(1)=XC1
IC(2)=XC2
IC(3)=XC3
IC(4)=XC4
IC(5)=XC5
IC(6)=XC6
IC(7)=XC7
IC(8)=XC8
IC(9)=XC9
IC(10)=XC10
IC(11)=XC11
IC(12)=XC12
IC(13)=XC13
IC(14)=XC14
IC(15)=XC15
IC(16)=XC16
DO 3172 I=1,16
IC(I)=IC(I)/(1000.0*ICTP(I))
```

```
 3172 CONTINUE
 3171 CONTINUE
      REWIND 2
 9888 TYPE 2006
  306 FORMAT(1X,' '/)
C
C     THE USER NOW SELECTS THE ORDER OF THE POLYNOMIAL CURVE
C     FIT EQUATION.  THE MAXIMUM ORDER IS ONE LESS THAN THE
C     NUMBER OF (X) DATA VALUES.
C
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      TYPE 301
  301 FORMAT(1X,'ENTER THE ORDER OF THE DESIRED POLYNOMIAL'/)
      TYPE 306
      TYPE 302
  302 FORMAT(1X,'(MAXIMUM = THE NUMBER OF SODIUM CHLORIDE'/
     C'             CALIBRATION CONCENTRATION STANDARDS  - 1)'/)
      TYPE 306
      TYPE 2004
      ACCEPT 303,M
  303 FORMAT(I2)
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      DO 403 JK=1,14
      W(JK-1)=0.0
      Z(JK-1)=0.0
  403 CONTINUE
      W(0)=NP
      DO 401 I=1,NP
      DO 400 J=1,2*M
      W(J)=W(J)+X(I)**J
      Z(J)=Z(J)+Y(I)*X(I)**J
  400 CONTINUE
      Z(0)=Z(0)+Y(I)
  401 CONTINUE
      DO 500 I=1,M+1
      DO 500 J=1,M+1
      B(I,J)=W(J-2+I)
      B(I,M+2)=Z(I-1)
  500 CONTINUE
C
C     THE FOLLOWING SERIES OF NESTED DO LOOPS ACCOMPLISH THE FOLLOWING:
C     THE FIRST INCREMENTS THE NESTED DO LOOP SYSTEM AND THUS SOLVES
C     FOR EACH POLYNOMIAL COEFFICIENT ON A SUCCESSIVE BASIS.
C
C     THE SECOND INCREMENTS THE NESTED DO LOOP SYSTEM AND THUS DECREASES
C     THE MATRIX SIZE BY ONE ROW AND COLUMN EACH ITERATON.
C
C     THE THIRD AND FOURTH TAKE THE ITH ROW AND DIVIDE IT BY ITS NTH
C     COEFFICIENT AND THEN MULTIPLIES THE ITH ROW BY THE NTH COEFFICIENT
C     OF THE (I+1)TH ROW.  FINALLY IT SUBTRACTS THE (I+1)TH ROW FROM THE
C     ITH ROW.
C
C     THE LAST TWO DO LOOPS RESTRUCTURE MATRIX B SO THAT IT CONTAINS THE
```

```
C     E MATRIX MINUS THE NTH COLUMN AND THE LAST ROW.
C
      DO 50 N=1,M+1
      DO 30 I1=1,M+1
      DO 30 J1=1,M+2
      D(I1,J1)=B(I1,J1)
   30 CONTINUE
      DO 40 K=1,M
      IF(N-K)35,35,33
   33 L=1
      GO TO 37
   35 L=2
   37 DO 31 I=1,M+1-K
      DO 31 J=1,M+3-K
      E(I,J)=(D(I,J)/D(I,L))*D(I+1,L)-D(I+1,J)
   31 CONTINUE
C
C     THE COEFFICIENTS FOR THE POLYNOMIAL LEAST-SQUARES CURVE FIT EQUATION
C     ARE CONTAINED IN THE 'A(N)' ARRAY.
C
      DO 40 I=1,M+1-K
      DO 40 J=1,M+2-K
      IF(J .GE. L) GO TO 45
      D(I,J)=E(I,J)
      GO TO 40
   45 D(I,J)=E(I,J+1)
   40 CONTINUE
      A(N)=D(1,2)/D(1,1)
   50 CONTINUE
      WRITE(3,2007)
      WRITE(3,51)M
C
C     OUTPUT THE CALCULATED INFORMATION INTO THE CALCX.XXX FILE.
C
   51 FORMAT(1X,24X,'THE ORDER OF THE DESIRED POLYNOMIAL= ',I2)
      WRITE(3,2006)
      WRITE(3,2006)
      IF(IAX.EQ.1) GO TO 52
      IF(IAX.EQ.2) GO TO 53
      IF(IAX.EQ.3) GO TO 54
      IF(IAX.EQ.4) GO TO 55
      IF(IAX.EQ.5) GO TO 56
      IF(IAX.EQ.6) GO TO 57
      IF(IAX.EQ.7) GO TO 58
      IF(IAX.EQ.8) GO TO 59
      IF(IAX.EQ.9) GO TO 60
   52 WRITE(3,61)
   61 FORMAT(1X,24X,'THE POLYNOMIAL FUNCTIONAL DEFINITION OF THE
     C VARIABLE (X) IS IN TERMS OF : (X)'///)
      GO TO 89
   53 WRITE(3,62)
   62 FORMAT(1X,24X,'THE POLYNOMIAL FUNCTIONAL DEFINITION OF THE
     C VARIABLE (X) IS IN TERMS OF:  (1/X)'///)
      GO TO 89
   54 WRITE(3,63)
   63 FORMAT(1X,24X,'THE POLYNOMIAL FUNCTIONAL DEFINITION OF THE
     C VARIABLE (X) IS IN TERMS OF:  (EXPONENTIAL (X))'///)
```

```
      GO TO 89
   55 WRITE(3,64)
   64 FORMAT(1X,24X,'THE POLYNOMIAL FUNCTIONAL DEFINITION OF THE
     C VARIABLE (X) IS IN TERMS OF:  (EXPONENTIAL (-X))'///)
      GO TO 89
   56 WRITE(3,65)
   65 FORMAT(1X,24X,'THE POLYNOMIAL FUNCTIONAL DEFINITION OF THE
     C VARIABLE (X) IS IN TERMS OF:  (EXPONENTIAL (1/X))'///)
      GO TO 89
   57 WRITE(3,66)
   66 FORMAT(1X,24X,'THE POLYNOMIAL FUNCTIONAL DEFINITION OF THE
     C VARIABLE (X) IS IN TERMS OF:  (EXPONENTIAL (-1/X))'///)
      GO TO 89
   58 WRITE(3,67)
   67 FORMAT(1X,24X,'THE POLYNOMIAL FUNCTIONAL DEFINITION OF THE
     C VARIABLE (X) IS IN TERMS OF:  (NATURAL LOG (X)'///)
      GO TO 89
   59 WRITE(3,68)
   68 FORMAT(1X,24X,'THE POLYNOMIAL FUNCTIONAL DEFINITION OF THE
     C VARIABLE (X) IS IN TERMS OF:  (LOG BASE TEN (X)'///)
      GO TO 89
   60 WRITE(3,69)
   69 FORMAT(1X,24X,'THE POLYNOMIAL FUNCTIONAL DEFINITION OF THE
     C VARIABLE (X) IS IN TERMS OF:  (SIN (X))'///)
      GO TO 89
   89 CONTINUE
      DO 90 I=1,M+1
      TYPE 70,I,A(I)
   71 FORMAT(1X,24X,'COEFFICIENT NUMBER',I3,'= '1PE15.5)
   70 FORMAT(1X,'COEFFICIENT NUMBER',I3,'= ',1PE15.5)
      WRITE(3,71)I,A(I)
   90 CONTINUE
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      TYPE 2006
   16 TYPE 19
   19 FORMAT(1X,'DO YOU WANT A LIST OF RESIDUALS ?'/
     C' (ANSWER YES OR NO) ',2X,$)
      ACCEPT 1002,CONMEN
      TYPE 2006
      IF(CONMEN .EQ. YES) GO TO 18
      IF(CONMEN .EQ. NO) GO TO 17
      IF(CONMEN .NE. YES .AND. CONMEN .NE. NO) GO TO 16
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
   18 WRITE(3,2007)
      WRITE(3,23)
   23 FORMAT(1X,24X,'THE RESIDUALS ARE CALCULATED BY THE FOLLOWING')
      WRITE(3,13)
   13 FORMAT(1X,24X,'EQUATION:  (Y(DATA)-Y(ESTIMATED))'//)
      WRITE(3,2006)
      WRITE(3,24)
   24 FORMAT(1X,18X,'SAMPLE NUMBER',17X,'YDATA',23X,'Y(ESTIMATED)',
     C19X,'RESIDUAL'/)
C
```

--APPENDIX A--

```
C     THE RESIDUALS ARE CALCULATED USING THE POLYNOMIAL CURVE
C     FIT EQUATION AND THE ORIGINAL DATA.
C
      SUMRES=0.0
      DO 15 K=1,NP
      THEORY=0.0
      DO 21 I=1,M+1
      IF(I .EQ. 1 .AND. X(K) .EQ. 0.0) GO TO 20
      THEORY=A(I)*X(K)**(I-1)+THEORY
      GO TO 21
   20 THEORY=A(I)*1.0**(I-1)+THEORY
   21 CONTINUE
C
C     CALCULATE THE SUM OF THE SQUARES RESIDUAL.
C
      RESID=Y(K)-THEORY
      SRESD=RESID*RESID
      SUMRES=SRESD + SUMRES
      TYPE 10,K,RESID
   10 FORMAT(1X,'SAMPLE NUMBER   ',I3,12X,'RESIDUAL= ',1PE15.5)
      WRITE(3,22)K,Y(K),THEORY,RESID
   22 FORMAT(1X,23X,I2,20X,1G13.6,18X,1G13.6,16X,1G13.6)
   15 CONTINUE
      TYPE 2006
      TYPE 72,SUMRES
   72 FORMAT(1X,'SUM OF THE SQUARE RESIDUALS= ',1PE15.5)
      TYPE 2007
      WRITE(3,2007)
      WRITE(3,73)SUMRES
   73 FORMAT(1X,24X,'SUM OF THE SQUARE RESIDUALS= ',1PE15.5)
   17 CONTINUE
C
C     CALCULATE INDIVIDUAL EXERCISE PROTECTION FACTORS
C
C
C     NOTE:  SINCE THE LEAK MEASURING SENSITIVITY OF THE SODIUM
C            CHLORIDE RQFT INSTRUMENT IS ONE PART IN TEN TO THE
C            SIXTH, ANY EXERCISE SCALED INTEGRATOR COUNT VALUE
C            YIELDING A PF GREATER THAN 1.0E+06, WILL BE
C            REPORTED AS 1.0E+06.  REPORTING A MASK LEAKAGE GREATER
C            THAN 1.0E+06 WOULD BE ERRONEOUS.  ANY EXERCISE SCALED
C            INTEGRATOR COUNT VALUE YIELDING A PROTECTION FACTOR
C            GREATER THAN 1.0 WILL BE REPORTED AS 1.0E+00.
C
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      IF(SELECT(7) .EQ. '2') GO TO 3173
      IDL=6
      IDLP=7
      GO TO 3174
 3173 CONTINUE
      IDL=16
      IDLP=17
 3174 CONTINUE
      PFEST=0.0
      DO 9173 I=1,IDL
```

```
      PF(I)=0.0
 9173 CONTINUE
      CALCPF=0.0
      DO 3057 I=1,IDL
      IF(IC(I).LE.XXAS(7)) GO TO 9227
      IF(IC(I).GE.XXAS(1)) GO TO 4136
      IF(IAX.EQ.1) PFEST=IC(I)
      IF(IAX.EQ.2) PFEST=1.0/IC(I)
      IF(IAX.EQ.3) PFEST=DEXP(IC(I))
      IF(IAX.EQ.4) PFEST=DEXP(-IC(I))
      IF(IAX.EQ.5) PFEST=DEXP(1.0/IC(I))
      IF(IAX.EQ.6) PFEST=DEXP(-1.0/IC(I))
      IF(IAX.EQ.7) PFEST=DLOG(IC(I))
      IF(IAX.EQ.8) PFEST=DLOG10(IC(I))
      IF(IAX.EQ.9) PFEST=DSIN(IC(I))
      CALCPF=0.0
      GO TO 9228
 9227 CALCPF=0.000001
      GO TO 3058
 4136 CALCPF=0.0
      GO TO 3058
 9228 DO 3058 J=1,M+1
      IF(J.EQ.1.AND.PFEST.EQ.0.0) GO TO 3059
      CALCPF=A(J)*PFEST**(J-1)+CALCPF
      GO TO 3058
 3059 CALCPF=A(J)*1.0**(J-1)+CALCPF
 3058 CONTINUE
C
C     BY DEFINITION, THE PROTECTION FACTOR (PF) IS:
C
C     PF = (CHALLENGE ATMOSPHERE CONCENTRATION)/(MASK LEAK CONCENTRATION)
C
C
      IF(CALCPF.NE.0.0) GO TO 4135
      PF(I)=0.0
      GO TO 3057
 4135 PF(I)=1.0/CALCPF
      PF(I)=1.0/CALCPF
 3057 CONTINUE
C
C     CALCULATE AN OVERALL ARITHMETIC AVERAGE PROTECTION FACTOR FOR ALL
C     EXERCISES.
C
      KOUNT=0
      PFSUM=0.0
      DO 3060 MT=1,IDL
      KOUNT=KOUNT + 1
      PFSUM=PFSUM + PF(MT)
 3060 CONTINUE
      PF(IDLP)=PFSUM/KOUNT
C
C
C     CALCULATE AN OVERALL TIME WEIGHTED AVERAGE PROTECTION FACTOR
C     FOR ALL EXERCISES.
C
C
      WPF=0.0
```

```
      KKOUNT=0
      PPSUM=0.0
      DO 3194 IMT=1,IDL
      KKOUNT=KKOUNT + ICTP(IMT)
      PPSUM=PPSUM + (PF(IMT)*ICTP(IMT))
 3194 CONTINUE
      WPF=PPSUM/KKOUNT
      WRITE(3,3061)
 3061 FORMAT(1H1)
      WRITE(3,3062)
 3062 FORMAT(6X,'THE DESCRIPTIVE AND PROTECTION FACTOR CALCULATIONS:'/)
      WRITE(3,9542)
 9542 FORMAT(6X,'NOTE:  ANY PROTECTION FACTOR THAT IS LISTED AS'/
     C'       1.0E+06 HAS BEEN ASSIGNED THIS VALUE BY DEFAULT'/
     C'       BECAUSE THE SENSITIVITY OF THIS RQFT INSTRUMENT IS'/
     C'       AT MOST ONE PART IN TEN TO THE SIXTH.  THE INTEGRATOR'/
     C'       COUNT VALUE FOR A PARTICULAR EXERCISE IN QUESTION'/
     C'       IS MERELY REPRESENTATIVE OF INTEGRATING THE ELECTRICAL'/
     C'       NOISE AND THE TRUE PROTECTION FACTOR IS INDEED LESS')
      WRITE(3,9543)
 9543 FORMAT(6X,'THAN 1.0E+06.  ANY EXERCISE SCALED INTEGRATOR'/
     C'       COUNT VALUE YIELDING A PROTECTION FACTOR GREATER'/
     C'       THAN 1.0 WILL BE REPORTED AS 0.0E-01.'//)
      WRITE(3,3176)
 3176 FORMAT(1X,' '//)
      TYPE 3062
      TYPE 2006
      TYPE 9542
      TYPE 9543
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      WRITE(3,3046)NAME
      WRITE(3,3047)MASK
      WRITE(3,3048)DATE
      WRITE(3,3049)TIME
      WRITE(3,3176)
      TYPE 3046,NAME
      TYPE 3047,MASK
      TYPE 3048,DATE
      TYPE 3049,TIME
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      WRITE(3,3063)
      TYPE 3063
 3063 FORMAT(6X,'EXERCISE',29X,'PROTECTION FACTOR'/)
      IF(SELECT(7) .EQ. '2') GO TO 3175
      WRITE(3,3064) PF(1)
      TYPE 3064,PF(1)
 3064 FORMAT(6X,'NORMAL BREATHING STRAIGHT AHEAD',6X,1PE12.1)
      WRITE(3,3065) PF(2)
      TYPE 3065,PF(2)
 3065 FORMAT(6X,'DEEP BREATHING STRAIGHT AHEAD',8X,1PE12.1)
      WRITE(3,3066) PF(3)
      TYPE 3066,PF(3)
 3066 FORMAT(6X,'TALKING',30X,1PE12.1)
```

```
      WRITE(3,3067) PF(4)
      TYPE 3067,PF(4)
3067 FORMAT(6X,'SIDE-TO-SIDE HEAD MOVEMENTS'/
    C'      (DEEP BREATHING)',21X,1PE12.1)
      WRITE(3,3068) PF(5)
      TYPE 3068,PF(5)
3068 FORMAT(6X,'UP-AND-DOWN HEAD MOVEMENTS'/
    C'      (DEEP BREATHING)',21X,1PE12.1)
      WRITE(3,3069) PF(6)
      TYPE 3069,PF(6)
3069 FORMAT(6X,'FACIAL GRIMACING',21X,1PE12.1////)
      WRITE(3,3070) PF(7)
      TYPE 3070,PF(7)
3070 FORMAT(1HO,5X,'OVERALL ARITHMETIC AVERAGE PROTECTION FACTOR '/
    C'      FOR ALL CATEGORIES OF EXERCISES ACTUALLY PERFORMED = '
    C,1PE8.1)
      TYPE 2006
      WRITE(3,2006)
      TYPE 3195,WPF
      WRITE(3,3195) WPF
3195 FORMAT(1HO,5X,'OVERALL TIME WEIGHTED AVERAGE PROTECTION FACTOR '/
    C'      FOR ALL CATEGORIES OF EXERCISES ACTUALLY PERFORMED = '
    C,1PE8.1)
      GO TO 3177
3175 CONTINUE
      WRITE(3,3178)PF(1)
      TYPE 3178,PF(1)
3178 FORMAT(6X,'NORMAL BREATHING STRAIGHT AHEAD',8X,1PE12.1)
      WRITE(3,3179)PF(2)
      TYPE 3179,PF(2)
3179 FORMAT(6X,'NORMAL BREATHING LEFT',18X,1PE12.1)
      WRITE(3,3180)PF(3)
      TYPE 3180,PF(3)
3180 FORMAT(6X,'NORMAL BREATHING RIGHT',17X,1PE12.1)
      WRITE(3,3181)PF(4)
      TYPE 3181,PF(4)
3181 FORMAT(6X,'NORMAL BREATHING DOWN',18X,1PE12.1)
      WRITE(3,3182)PF(5)
      TYPE 3182,PF(5)
3182 FORMAT(6X,'NORMAL BREATHING UP',20X,1PE12.1)
      WRITE(3,3183)PF(6)
      TYPE 3183,PF(6)
3183 FORMAT(6X,'DEEP BREATHING STRAIGHT AHEAD',10X,1PE12.1)
      WRITE(3,3184)PF(7)
      TYPE 3184,PF(7)
3184 FORMAT(6X,'DEEP BREATHING LEFT',20X,1PE12.1)
      WRITE(3,3185)PF(8)
      TYPE 3185,PF(8)
3185 FORMAT(6X,'DEEP BREATHING RIGHT',19X,1PE12.1)
      WRITE(3,3186)PF(9)
      TYPE 3186,PF(9)
3186 FORMAT(6X,'DEEP BREATHING DOWN',20X,1PE12.1)
      WRITE(3,3187)PF(10)
      TYPE 3187,PF(10)
3187 FORMAT(6X,'DEEP BREATHING UP',22X,1PE12.1)
      WRITE(3,3188)PF(11)
      TYPE 3188,PF(11)
```

```
 3188 FORMAT(6X,'TALKING',32X,1PE12.1)
      WRITE(3,3189)PF(12)
      TYPE 3189,PF(12)
 3189 FORMAT(6X,'FACIAL GRIMACING',23X,1PE12.1)
      WRITE(3,3190)PF(13)
      TYPE 3190,PF(13)
 3190 FORMAT(6X,'SIDE-TO-SIDE HEAD MOVEMENTS'/
     C'        (NORMAL BREATHING)',21X,1PE12.1)
      WRITE(3,3191)PF(14)
      TYPE 3191,PF(14)
 3191 FORMAT(6X,'UP-AND-DOWN HEAD MOVEMENTS'/
     C'        (NORMAL BREATHING)',21X,1PE12.1)
      WRITE(3,3192)PF(15)
      TYPE 3192,PF(15)
 3192 FORMAT(6X,'SIDE-TO-SIDE HEAD MOVEMENTS'/
     C'        (DEEP BREATHING)',23X,1PE12.1)
      WRITE(3,3193)PF(16)
      TYPE 3193,PF(16)
 3193 FORMAT(6X,'UP-AND-DOWN HEAD MOVEMENTS'/
     C'        (DEEP BREATHING)',23X,1PE12.1////)
      WRITE(3,3070)PF(IDLP)
      TYPE 3070,PF(IDLP)
      TYPE 2006
      WRITE(3,3176)
      TYPE 3195,WPF
      WRITE(3,3195)WPF
 3177 CONTINUE
      TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
C
C     FORM THE ARRAYS FOR PLOTTING PURPOSES AND LOAD THEM INTO THE
C     FILE CALLED GRPHX.XXX.
C
C
C     FIND THE MINIMUM AND MAXIMUM OF THE (X) DATA VALUES
C     AND FORM A DELTA ELEMENT SO THAT INTERMEDIATE VALUES
C     CAN BE CALCULATED USING THE POLYNOMIAL CURVE FIT EQUATION.
C
      TYPE 3061
      DO 2 I=1,NP
      GRPH1(I)=XXAS(I)
    2 CONTINUE
      N1=NP-1
      DO 8 I=1,N1
      I1=I + 1
      DO 8 J=I1,NP
      IF(XAS(J).GE.XAS(I)) GO TO 8
      XSAVE=XAS(I)
      XAS(I)=XAS(J)
      XAS(J)=XSAVE
    8 CONTINUE
      XMIN=XAS(1)
      XMAX=XAS(NP)
      DEL=(XMAX-XMIN)/400.0
      XXX=XMIN-DEL
      DO 7 KA=1,401
```

--APPENDIX A--

```
      XXX=XXX + DEL
      XX(KA)=XXX
      XXXX=XXX
      IF(IAX.EQ.1) XEST=XXXX
      IF(IAX.EQ.2) XEST=1.0/XXXX
      IF(IAX.EQ.3) XEST=DEXP(XXXX)
      IF(IAX.EQ.4) XEST=DEXP(-XXXX)
      IF(IAX.EQ.5) XEST=DEXP(1.0/XXXX)
      IF(IAX.EQ.6) XEST=DEXP(-1.0/XXXX)
      IF(IAX.EQ.7) XEST=DLOG(XXXX)
      IF(IAX.EQ.8) XEST=DLOG10(XXXX)
      IF(IAX.EQ.9) XEST=DSIN(XXXX)
      BEGIN=0.0
      DO 6 KB=1,M+1
      IF(KB.EQ.1.AND.XEST.EQ.0.0) GO TO 5
      BEGIN=A(KB)*XEST**(KB-1)+BEGIN
      GO TO 6
    5 BEGIN=A(KB)*1.0**(KB-1)+BEGIN
    6 CONTINUE
      YY(KA)=BEGIN
    7 CONTINUE
      DO 4 I=1,401
      GRPH2(I)=XX(I)
    4 CONTINUE
      DO 3 I=1,401
      GRPH2(I+401)=YY(I)
    3 CONTINUE
      DO 1 I=1,NP
      GRPH1(I+NP)=Y(I)
    1 CONTINUE
C
C     OUTPUT THE INFORMATION THAT CAN BE USED FOR GENERATING A
C     CALIBRATION PLOT INTO THE FILE CALLED GRPHX.XXX.
C
      WRITE(1,2007)
      WRITE(1,9)
    9 FORMAT(1X,24X,'THE ARRAYS FOR PLOTTING'///)
      WRITE(1,2007)
      WRITE(1,3006)
 3006 FORMAT(1X,24X,'GRPH1 ARRAY CONTAINS THE SODIUM CHLORIDE
     C CALIBRATION STANDARD DATA'///)
      WRITE(1,3004)
 3004 FORMAT(1X,24X,'SAMPLE NUMBER',19X,'VALUE'/)
      DO 34 I=1,NP*2
      WRITE(1,3005)I,GRPH1(I)
 3005 FORMAT(1X,28X,I3,22X,1G13.6)
   34 CONTINUE
      WRITE(1,2007)
      WRITE(1,3007)
 3007 FORMAT(1X,24X,'GRPH2 ARRAY CONTAINS THE ESTIMATED VALUES'///)
      WRITE(1,3004)
      DO 32 I=1,802
      WRITE(1,3005)I,GRPH2(I)
   32 CONTINUE
   29 TYPE 2006
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
```

```
      TYPE 27
   27 FORMAT(1X,'DO YOU WISH TO USE THE SAME SODIUM CHLORIDE STANDARD'/
     C' CALIBRATION VOLTAGE MEASUREMENTS AND EXERCISE INTEGRATOR COUNT'/
     C' DATA BUT CALCULATE A DIFFERENT DEGREE OR FORM OF THE'/
     C' POLYNOMIAL CURVE FITTING FUNCTION? (ANSWER YES OR NO)',2X,$)
      ACCEPT 1002,REP
      IF(REP.EQ.YES) GO TO 6000
      IF(REP.EQ.NO) GO TO 28
      IF(REP.NE.YES.AND.REP.NE.NO) GO TO 29
   28 CONTINUE
      CLOSE(UNIT=2)
      CLOSE(UNIT=3)
      CLOSE(UNIT=1)
 9674 TYPE 2007
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2006
      TYPE 14
   14 FORMAT(1X,'DO YOU WISH TO CALCULATE PROTECTION FACTORS FOR'/
     C' ANY OR ALL OF THE FOLLOWING CONDITIONS:  1) A DIFFERENT'/
     C' SUBJECT   2) A DIFFERENT SET OF SODIUM CHLORIDE CALIBRATION'/
     C' STANDARD VOLTAGE MEASUREMENTS   3) A DIFFERENT SET OF'/
     C' EXERCISE INTEGRATOR COUNT DATA.'/)
      TYPE 9999
 9999 FORMAT(1X,'(ANSWER YES OR NO)',2X,$)
      ACCEPT 1002,COM
      IF(COM.EQ.YES) GO TO 5101
      IF(COM.EQ.NO) GO TO 9672
      IF(COM.NE.YES.AND.COM.NE.NO) GO TO 9674
 9672 CONTINUE
      TYPE 2007
      TYPE 4137,ICCBS(1),ICCBS(2)
      TYPE 2007
      TYPE 9599
 9599 FORMAT(1X,12X,'JOB SUCCESSFULLY COMPLETED',//////)
      STOP
      END
C
C
C     SUBROUTINE CLEAR IS CALLED WHEN ENTERRING DATA IN THE
C     SODIUM CHLORIDE CALIBRATION CONCENTRATION STANDARDS
C     SECTION AND EXERCISE INTEGRATOR COUNT SECTION.  BY
C     CALLING THIS SUBROUTINE THE OPERATOR CAN MAKE TWO
C     DATA ENTRIES ON THE SAME LINE.  SUBROUTINE CLEAR ERASES
C     THE LINE INWHICH THE FIRST DATA ENTRY WAS MADE AND
C     RETYPES THAT LINE, INCLUDING THE FIRST DATA ENTRY;
C     THIS ALLOWS A SECOND ENTRY TO BE MADE ON THAT LINE.
C
C
      SUBROUTINE CLEAR(LINES)
      BYTE A(3)
      A(1)=27
      A(2)=65
      A(3)=75
      IF (LINES.EQ.0) LINES=1
      DO 1 I=1,LINES
    1 TYPE 4,A(1),A(2),A(1),A(3)
      LINES=0
```

```
      RETURN
    4 FORMAT (1H+,4A1,$)
      END
```

APPENDIX B:

DATA.XXX File Contents for Data in Table 7

--APPENDIX B--

THE NUMBER OF SODIUM CHLORIDE CALIBRATION CONCENTRATION STANDARDS= 7

SAMPLE NUMBER	VOLTAGE MEASUREMENT (IN VOLTS) (X DATA)	SODIUM CHLORIDE CALIBRATION CONCENTRATION (Y DATA)
1	3.38000	1.00000
2	2.91500	0.100000
3	2.31000	0.100000E-01
4	1.50000	0.100000E-02
5	0.545000	0.100000E-03
6	0.165000	0.100000E-04
7	0.105000	0.100000E-05

SUBJECT NAME: CAPTAIN EDWARD S. KOLESAR, JR.
TYPE OF MASK: USA ; M17 - MEDIUM - NO GLASSES
DATE TESTED : 9 APRIL 1980
TIME TESTED : 1330 HOURS

EXERCISE INTEGRATOR COUNT DATA:

EXERCISE	INTEGRATOR COUNT	TIME PERIOD (IN SECONDS)
NORMAL BREATHING STRAIGHT AHEAD	3904	10
DEEP BREATHING STRAIGHT AHEAD	4751	10
TALKING	4628	10
SIDE-TO-SIDE HEAD MOVEMENTS (DEEP BREATHING)	3976	10
UP-AND-DOWN HEAD MOVEMENTS (DEEP BREATHING)	4016	10
FACIAL GRIMACING	4937	10

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APPENDIX C:

CALCX.XXX File Contents for Information in Table 8

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--APPENDIX C--

THE ORDER OF THE DESIRED POLYNOMIAL= 6

THE POLYNOMIAL FUNCTIONAL DEFINITION OF THE VARIABLE (X) IS IN TERMS OF: (EXPONENTIAL (X))

COEFFICIENT NUMBER 1= -4.17904E-05
COEFFICIENT NUMBER 2= -7.31407E-05
COEFFICIENT NUMBER 3= 1.25863E-04
COEFFICIENT NUMBER 4= -2.68095E-05
COEFFICIENT NUMBER 5= 3.80138E-06
COEFFICIENT NUMBER 6= -1.71541E-07
COEFFICIENT NUMBER 7= 3.83406E-09

THE RESIDUALS ARE CALCULATED BY THE FOLLOWING
EQUATION: (Y(DATA)-Y(ESTIMATED))

SAMPLE NUMBER	Y(DATA)	Y(ESTIMATED)	RESIDUAL
1	1.00000	1.00000	-0.403548E-07
2	0.100000	0.100000	-0.109111E-07
3	0.100000E-01	0.100000E-01	-0.711342E-0[illegible]
4	0.100000E-02	0.100000E-02	-0.401929E-0[illegible]
5	0.100000E-03	0.100004E-03	-0.390294E-0[illegible]
6	0.100000E-04	0.100034E-04	-0.340602E-0[illegible]
7	0.100000E-05	0.100433E-05	-0.432502E-0[illegible]

SUM OF THE SQUARE RESIDUALS= 2.00011E-15

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--APPENDIX C--

THE DESCRIPTIVE AND PROTECTION FACTOR CALCULATIONS:

NOTE: ANY PROTECTION FACTOR THAT IS LISTED AS 1.0E+06 HAS BEEN ASSIGNED THIS VALUE BY DEFAULT BECAUSE THE SENSITIVITY OF THIS ROFT INSTRUMENT IS AT MOST ONE PART IN TEN TO THE SIXTH. THE INTEGRATOR COUNT VALUE FOR A PARTICULAR EXERCISE IN QUESTION IS MERELY REPRESENTATIVE OF INTEGRATING THE ELECTRICAL NOISE AND THE TRUE PROTECTION FACTOR IS INDEED LESS THAN 1.0E+06. ANY EXERCISE SCALED INTEGRATOR COUNT VALUE YIELDING A PROTECTION FACTOR GREATER THAN 1.0 WILL BE REPORTED AS 0.0E-01.

SUBJECT NAME: CAPTAIN EDWARD S. KOLESAR, JR.
TYPE OF MASK: USA : M17 - MEDIUM - NO GLASSES
DATE TESTED : 9 APRIL 1980
TIME TESTED : 1330 HOURS

EXERCISE	PROTECTION FACTOR
NORMAL BREATHING STRAIGHT AHEAD	1.8E+04
DEEP BREATHING STRAIGHT AHEAD	1.3E+04
TALKING	1.3E+04
SIDE-TO-SIDE HEAD MOVEMENTS (DEEP BREATHING)	1.7E+04
UP-AND-DOWN HEAD MOVEMENTS (DEEP BREATHING)	1.7E+04
FACIAL GRIMACING	1.2E+04

OVERALL ARITHMETIC AVERAGE PROTECTION FACTOR
FOR ALL CATEGORIES OF EXERCISES ACTUALLY PERFORMED = 1.5E+04

OVERALL TIME WEIGHTED AVERAGE PROTECTION FACTOR
FOR ALL CATEGORIES OF EXERCISES ACTUALLY PERFORMED = 1.5E+04

APPENDIX D:

GRPHX.XXX File Contents for Use with NACLGRAPH.FTN Program

--APPENDIX D--

THE ARRAYS FOR PLOTTING

GPPH1 ARRAY CONTAINS THE SODIUM CHLORIDE CALIBRATION STANDARD DATA

SAMPLE NUMBER	VALUE
1	3.38000
2	2.91500
3	2.31000
4	1.50000
5	0.545000
6	0.165000
7	0.105000
8	1.00000
9	0.100000
10	0.100000E-01
11	0.100000E-02
12	0.100000E-03
13	0.100000E-04
14	0.100000E-05

GRPH2 ARRAY CONTAINS THE ESTIMATED VALUES

SAMPLE NUMBER	VALUE
1	0.105000
2	0.113187
3	0.121375
4	0.129562
5	0.137750
6	0.145938
7	0.154125
8	0.162313
9	0.170500
10	0.178687

--APPENDIX D--

11	0.186875
12	0.195063
13	0.203250
14	0.211438
15	0.219625
16	0.227812
17	0.236000
18	0.244188
19	0.252375
20	0.260563
21	0.268750
22	0.276938
23	0.285125
24	0.293313
25	0.301500
26	0.309687
27	0.317875
28	0.326063
29	0.334250
30	0.342438
31	0.350625
32	0.358813
33	0.367000
34	0.375188
35	0.383375
36	0.391563
37	0.399750
38	0.407937
39	0.416125
40	0.424313
41	0.432500
42	0.440688
43	0.448875
44	0.457063
45	0.465250
46	0.473438
47	0.481625
48	0.489813
49	0.498000
50	0.506187
51	0.514375
52	0.522563
53	0.530750
54	0.538938
55	0.547125
56	0.555313
57	0.563500
58	0.571688
59	0.579875
60	0.588063
61	0.596250
62	0.604438
63	0.612625
64	0.620813
65	0.629000
66	0.637188
67	0.645375
68	0.653563
69	0.661750
70	0.669937
71	0.678125

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72	0.686312
73	0.694500
74	0.702688
75	0.710875
76	0.719063
77	0.727250
78	0.735438
79	0.743625
80	0.751813
81	0.760000
82	0.768188
83	0.776375
84	0.784563
85	0.792750
86	0.800938
87	0.809125
88	0.817313
89	0.825500
90	0.833688
91	0.841875
92	0.850063
93	0.858250
94	0.866438
95	0.874625
96	0.882812
97	0.891000
98	0.899188
99	0.907375
100	0.915563
101	0.923750
102	0.931938
103	0.940125
104	0.948313
105	0.956500
106	0.964688
107	0.972875
108	0.981063
109	0.989250
110	0.997438
111	1.00563
112	1.01381
113	1.02200
114	1.03019
115	1.03838
116	1.04656
117	1.05475
118	1.06294
119	1.07113
120	1.07931
121	1.08750
122	1.09569
123	1.10388
124	1.11206
125	1.12025
126	1.12844
127	1.13663
128	1.14481
129	1.15300
130	1.16119
131	1.16938
132	1.17756

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133	1.18575
134	1.19394
135	1.20213
136	1.21031
137	1.21850
138	1.22669
139	1.23488
140	1.24306
141	1.25125
142	1.25944
143	1.26763
144	1.27581
145	1.28400
146	1.29219
147	1.30037
148	1.30856
149	1.31675
150	1.32494
151	1.33312
152	1.34131
153	1.34950
154	1.35769
155	1.36588
156	1.37406
157	1.38225
158	1.39044
159	1.39863
160	1.40681
161	1.41500
162	1.42319
163	1.43138
164	1.43956
165	1.44775
166	1.45594
167	1.46413
168	1.47231
169	1.48050
170	1.48869
171	1.49688
172	1.50506
173	1.51325
174	1.52144
175	1.52963
176	1.53781
177	1.54600
178	1.55419
179	1.56238
180	1.57056
181	1.57875
182	1.58694
183	1.59513
184	1.60331
185	1.61150
186	1.61969
187	1.62788
188	1.63606
189	1.64425
190	1.65244
191	1.66063
192	1.66881
193	1.67700

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194	1.68519
195	1.69338
196	1.70156
197	1.70975
198	1.71794
199	1.72613
200	1.73431
201	1.74250
202	1.75069
203	1.75888
204	1.76706
205	1.77525
206	1.78344
207	1.79163
208	1.79981
209	1.80800
210	1.81619
211	1.82438
212	1.83256
213	1.84075
214	1.84894
215	1.85713
216	1.86531
217	1.87350
218	1.88169
219	1.88988
220	1.89806
221	1.90625
222	1.91444
223	1.92263
224	1.93081
225	1.93900
226	1.94719
227	1.95538
228	1.96356
229	1.97175
230	1.97994
231	1.98813
232	1.99631
233	2.00450
234	2.01269
235	2.02087
236	2.02906
237	2.03725
238	2.04544
239	2.05363
240	2.06181
241	2.07000
242	2.07819
243	2.08637
244	2.09456
245	2.10275
246	2.11094
247	2.11913
248	2.12731
249	2.13550
250	2.14369
251	2.15188
252	2.16006
253	2.16825
254	2.17644

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255	2.18463
256	2.19281
257	2.20100
258	2.20919
259	2.21738
260	2.22556
261	2.23375
262	2.24194
263	2.25013
264	2.25831
265	2.26650
266	2.27469
267	2.28288
268	2.29106
269	2.29925
270	2.30744
271	2.31563
272	2.32381
273	2.33200
274	2.34019
275	2.34838
276	2.35656
277	2.36475
278	2.37294
279	2.38112
280	2.38931
281	2.39750
282	2.40569
283	2.41388
284	2.42206
285	2.43025
286	2.43844
287	2.44662
288	2.45481
289	2.46300
290	2.47119
291	2.47938
292	2.48756
293	2.49575
294	2.50394
295	2.51213
296	2.52031
297	2.52850
298	2.53669
299	2.54488
300	2.55306
301	2.56125
302	2.56944
303	2.57763
304	2.58581
305	2.59400
306	2.60219
307	2.61038
308	2.61856
309	2.62675
310	2.63494
311	2.64313
312	2.65131
313	2.65950
314	2.66769
315	2.67588

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316	2.68406
317	2.69225
318	2.70044
319	2.70863
320	2.71681
321	2.72500
322	2.73319
323	2.74138
324	2.74956
325	2.75775
326	2.76594
327	2.77413
328	2.78231
329	2.79050
330	2.79869
331	2.80687
332	2.81506
333	2.82325
334	2.83144
335	2.83963
336	2.84781
337	2.85600
338	2.86419
339	2.87238
340	2.88056
341	2.88875
342	2.89694
343	2.90513
344	2.91331
345	2.92150
346	2.92969
347	2.93788
348	2.94606
349	2.95425
350	2.96244
351	2.97063
352	2.97881
353	2.98700
354	2.99519
355	3.00338
356	3.01156
357	3.01975
358	3.02794
359	3.03613
360	3.04431
361	3.05250
362	3.06069
363	3.06888
364	3.07706
365	3.08525
366	3.09344
367	3.10163
368	3.10981
369	3.11800
370	3.12619
371	3.13438
372	3.14256
373	3.15075
374	3.15894
375	3.16713
376	3.17531

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377	3.18350
378	3.19169
379	3.19988
380	3.20806
381	3.21625
382	3.22444
383	3.23263
384	3.24081
385	3.24900
386	3.25719
387	3.26538
388	3.27356
389	3.28175
390	3.28994
391	3.29813
392	3.30631
393	3.31450
394	3.32269
395	3.33088
396	3.33906
397	3.34725
398	3.35544
399	3.36363
400	3.37181
401	3.38000
402	0.100432E-05
403	0.216730E-05
404	0.335033E-05
405	0.455367E-05
406	0.577763E-05
407	0.702248E-05
408	0.828852E-05
409	0.957605E-05
410	0.108854E-04
411	0.122168E-04
412	0.135706E-04
413	0.149471E-04
414	0.163466E-04
415	0.177694E-04
416	0.192160E-04
417	0.206865E-04
418	0.221813E-04
419	0.237007E-04
420	0.252452E-04
421	0.268150E-04
422	0.284104E-04
423	0.300319E-04
424	0.316797E-04
425	0.333543E-04
426	0.350560E-04
427	0.367851E-04
428	0.385421E-04
429	0.403273E-04
430	0.421411E-04
431	0.439839E-04
432	0.458560E-04
433	0.477579E-04
434	0.496900E-04
435	0.516527E-04
436	0.536463E-04
437	0.556714E-04

438	0.577283E-04
439	0.598174E-04
440	0.619392E-04
441	0.640942E-04
442	0.662827E-04
443	0.685053E-04
444	0.707623E-04
445	0.730542E-04
446	0.753816E-04
447	0.777449E-04
448	0.801445E-04
449	0.825810E-04
450	0.850548E-04
451	0.875665E-04
452	0.901165E-04
453	0.927055E-04
454	0.953338E-04
455	0.980021E-04
456	0.100711E-03
457	0.103461E-03
458	0.106252E-03
459	0.109086E-03
460	0.111962E-03
461	0.114881E-03
462	0.117845E-03
463	0.120853E-03
464	0.123906E-03
465	0.127005E-03
466	0.130150E-03
467	0.133342E-03
468	0.136582E-03
469	0.139870E-03
470	0.143207E-03
471	0.146594E-03
472	0.150031E-03
473	0.153519E-03
474	0.157059E-03
475	0.160692E-03
476	0.164290E-03
477	0.167998E-03
478	0.171753E-03
479	0.175564E-03
480	0.179430E-03
481	0.183355E-03
482	0.187337E-03
483	0.191378E-03
484	0.195480E-03
485	0.199641E-03
486	0.203865E-03
487	0.208151E-03
488	0.212501E-03
489	0.216915E-03
490	0.221395E-03
491	0.225941E-03
492	0.230555E-03
493	0.235237E-03
494	0.239989E-03
495	0.2448[illegible]2E-03
496	0.249706E-03
497	0.254674E-03
498	0.259716E-03

--APPENDIX D--

499	0.264834E-03
500	0.270028E-03
501	0.275300E-03
502	0.280652E-03
503	0.286084E-03
504	0.291598E-03
505	0.297196E-03
506	0.302878E-03
507	0.308647E-03
508	0.314504E-03
509	0.320450E-03
510	0.326488E-03
511	0.332617E-03
512	0.338842E-03
513	0.345162E-03
514	0.351580E-03
515	0.358098E-03
516	0.364718E-03
517	0.371441E-03
518	0.378269E-03
519	0.385205E-03
520	0.392251E-03
521	0.399409E-03
522	0.406680E-03
523	0.414068E-03
524	0.421575E-03
525	0.439203E-03
526	0.436954E-03
527	0.444831E-03
528	0.452838E-03
529	0.460976E-03
530	0.469248E-03
531	0.477658E-03
532	0.486208E-03
533	0.494901E-03
534	0.503741E-03
535	0.512731E-03
536	0.521874E-03
537	0.531174E-03
538	0.540634E-03
539	0.550258E-03
540	0.560049E-03
541	0.570013E-03
542	0.580153E-03
543	0.590472E-03
544	0.600976E-03
545	0.611669E-03
546	0.622555E-03
547	0.633640E-03
548	0.644928E-03
549	0.656424E-03
550	0.668134E-03
551	0.680063E-03
552	0.692217E-03
553	0.704601E-03
554	0.717221E-03
555	0.730084E-03
556	0.743196E-03
557	0.756563E-03
558	0.770193E-03
559	0.784092E-03

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560	0.798268E-03
561	0.812729E-03
562	0.827481E-03
563	0.842533E-03
564	0.857894E-03
565	0.873571E-03
566	0.889574E-03
567	0.905912E-03
568	0.922595E-03
569	0.939631E-03
570	0.957032E-03
571	0.974808E-03
572	0.992969E-03
573	0.101153E-02
574	0.103049E-02
575	0.104988E-02
576	0.106970E-02
577	0.108996E-02
578	0.111068E-02
579	0.113187E-02
580	0.115355E-02
581	0.117573E-02
582	0.119843E-02
583	0.122165E-02
584	0.124543E-02
585	0.126976E-02
586	0.129468E-02
587	0.132019E-02
588	0.134633E-02
589	0.137309E-02
590	0.140051E-02
591	0.142861E-02
592	0.145740E-02
593	0.148692E-02
594	0.151717E-02
595	0.154818E-02
596	0.157998E-02
597	0.161259E-02
598	0.164604E-02
599	0.168035E-02
600	0.171554E-02
601	0.175166E-02
602	0.178873E-02
603	0.182676E-02
604	0.186581E-02
605	0.190590E-02
606	0.194706E-02
607	0.198932E-02
608	0.203272E-02
609	0.207731E-02
610	0.212310E-02
611	0.217015E-02
612	0.221850E-02
613	0.226817E-02
614	0.231923E-02
615	0.237170E-02
616	0.242565E-02
617	0.248110E-02
618	0.253812E-02
619	0.259675E-02
620	0.265705E-02

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621	0.271906E-02
622	0.278284E-02
623	0.284846E-02
624	0.291596E-02
625	0.298541E-02
626	0.305687E-02
627	0.313041E-02
628	0.320608E-02
629	0.328398E-02
630	0.336415E-02
631	0.344668E-02
632	0.353164E-02
633	0.361911E-02
634	0.370918E-02
635	0.380192E-02
636	0.389742E-02
637	0.399577E-02
638	0.409706E-02
639	0.420139E-02
640	0.430885E-02
641	0.441955E-02
642	0.453359E-02
643	0.465108E-02
644	0.477213E-02
645	0.489685E-02
646	0.502537E-02
647	0.515780E-02
648	0.529427E-02
649	0.543492E-02
650	0.557987E-02
651	0.572927E-02
652	0.588326E-02
653	0.604199E-02
654	0.620562E-02
655	0.637429E-02
656	0.654818E-02
657	0.672745E-02
658	0.691229E-02
659	0.710286E-02
660	0.729935E-02
661	0.750197E-02
662	0.771090E-02
663	0.792636E-02
664	0.814855E-02
665	0.837769E-02
666	0.861402E-02
667	0.885776E-02
668	0.910916E-02
669	0.936848E-02
670	0.963596E-02
671	0.991188E-02
672	0.101965E-01
673	0.104901E-01
674	0.107931E-01
675	0.111056E-01
676	0.114281E-01
677	0.117608E-01
678	0.121041E-01
679	0.124584E-01
680	0.128239E-01
681	0.132012E-01

682	0.135905E-01
683	0.139923E-01
684	0.144070E-01
685	0.148351E-01
686	0.152769E-01
687	0.157330E-01
688	0.162038E-01
689	0.166899E-01
690	0.171917E-01
691	0.177099E-01
692	0.182449E-01
693	0.187974E-01
694	0.193679E-01
695	0.199570E-01
696	0.205656E-01
697	0.211941E-01
698	0.218433E-01
699	0.225140F-01
700	0.232068E-01
701	0.239227E-01
702	0.246623E-01
703	0.254267E-01
704	0.262165E-01
705	0.270329E-01
706	0.278767E-01
707	0.287489E-01
708	0.296506E-01
709	0.305829E-01
710	0.315469E-01
711	0.325438E-01
712	0.335748E-01
713	0.346412E-01
714	0.357443E-01
715	0.368856E-01
716	0.380665E-01
717	0.392885E-01
718	0.405533E-01
719	0.418624E-01
720	0.432177E-01
721	0.446209E-01
722	0.460739E-01
723	0.475787E-01
724	0.491375E-01
725	0.507523E-01
726	0.524255E-01
727	0.541594E-01
728	0.559565E-01
729	0.578195E-01
730	0.597510E-01
731	0.617540E-01
732	0.638314E-01
733	0.659864E-01
734	0.682223E-01
735	0.705426E-01
736	0.729509E-01
737	0.754510E-01
738	0.780469E-01
739	0.807429E-01
740	0.835433E-01
741	0.864528E-01
742	0.894763E-01

--APPENDIX D--

743	0.926189E-01
744	0.958860E-01
745	0.992832E-01
746	0.102816
747	0.106492
748	0.110317
749	0.114297
750	0.118441
751	0.122755
752	0.127248
753	0.131929
754	0.136806
755	0.141889
756	0.147187
757	0.152711
758	0.158473
759	0.164483
760	0.170755
761	0.177300
762	0.184133
763	0.191267
764	0.198718
765	0.206502
766	0.214636
767	0.223137
768	0.232024
769	0.241316
770	0.251035
771	0.261202
772	0.271840
773	0.282975
774	0.294631
775	0.306835
776	0.319618
777	0.333007
778	0.347037
779	0.361740
780	0.377152
781	0.393310
782	0.410255
783	0.428028
784	0.446673
785	0.466237
786	0.486770
787	0.508323
788	0.530952
789	0.554714
790	0.579671
791	0.605887
792	0.633431
793	0.662376
794	0.692797
795	0.724775
796	0.758395
797	0.793747
798	0.830926
799	0.870032
800	0.911171
801	0.954454
802	1.00000

APPENDIX E:

NACLGRAPH.FTN Fortran Listing

--APPENDIX E--

```
      DIMENSION XY1(50),XY2(810),TTL4(5),NOE(2),IPTTL(4)
      DIMENSION IPCRV(2),KTYPE(2),TTL3(4),NTTL(4),TSIZE(4),RYTTL(4)
      BYTE XTL(40),YTL(40),TTL(240),DNAME(130),PNAME(13)
      BYTE YES,NO,ANS,SYMB
      BYTE RED,GREEN,BLACK,PSCL,PTL,PCRV,ESC,HOME,CLR
      COMMON/GRPH/YTLRX,XTLRY
      DATA YES/'Y'/
      DATA NO/'N'/
      DATA RED/'R'/
      DATA GREEN/'G'/
      DATA BLACK/'B'/
      DATA TTL3/'= AC','TUAL',' DAT','A'/
      DATA TTL4/'= ES','TIMA','TED ','VALU','ES'/
      ESC=27
      HOME=72
      CLR=74
      SYMB=1
      ISCL=0
      CALL ERRSET(64,.TRUE.,.TRUE.,.TRUE.,.FALSE.,30)
      CALL ERRSET(29,.TRUE.,.TRUE.,.TRUE.,.FALSE.,30)
      CALL ERRSET(43,.TRUE.,.TRUE.,.FALSE.,.FALSE.,30)
      CALL ERRSET(59,.TRUE.,.FALSE.,.TRUE.,.FALSE.,30)
      CALL ERRSET(30,.TRUE.,.FALSE.,.TRUE.,.FALSE.,30)
11          CONTINUE
      WRITE(5,555) ESC,HOME,ESC,CLR
      WRITE(5,415)
1     READ(5,405,ERR=2) IRW
      IF(IRW.EQ.1.OR.IRW.EQ.2.OR.IRW.EQ.3) GO TO 3
2     WRITE(5,155)
      GO TO 1
3     IF(IRW.EQ.2.OR.IRW.EQ.3) IRLUN=5
      IF(IRW.EQ.1) IRLUN=1
      WRITE(5,65)
10          READ(5,55) LENP,(PNAME(I),I=1,12)
      IF(LENP.GT.12) GO TO 20
      PNAME(LENP+1)=0
      CALL ERRTST(43,K)
      CALL ASSIGN(2,PNAME)
      CALL ASSIGN(4,'GRAPH1.TXT')
      IF(IRW.NE.3) CALL ASSIGN(1,'GRAPH1.COM')
      CALL ERRTST(43,K)
      IF(K.EQ.2) GO TO 21
20          WRITE(5,115)
      GO TO 10
21          WRITE(4,65)
      WRITE(4,305) (PNAME(I),I=1,LENP)
30          ISCL=ISCL+1
      IXMM=0
      IYMM=0
      WRITE(5,555) ESC,HOME,ESC,CLR
      NDIG=2
      IF(ISCL.LT.10) NDIG=1
      IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,355) ISCL
      IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,465)
40          READ(IRLUN,105) LEN,ANS
```

```
      IF(LEN.EQ.0) ANS='N'
      IF(ANS.EQ.YES.OR.ANS.EQ.NO) GO TO 50
      WRITE(5,155)
      GO TO 40
50          IF(ANS.EQ.YES) IXMM=1
      IF(IXMM.EQ.0) GO TO 110
      IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,485)
60          READ(IRLUN,*,ERR=70) XMIN
      GO TO 80
70          WRITE(5,155)
      GO TO 60
80          IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,495)
90          READ(IRLUN,*,ERR=100) XMAX
      GO TO 110
100         WRITE(5,155)
      GO TO 90
110         WRITE(4,245)
      WRITE(4,355) ISCL
      WRITE(4,465)
      WRITE(4,265) ANS
      IF(IRW.EQ.2) WRITE(1,585) ANS
      IF(ANS.EQ.NO) GO TO 111
      WRITE(4,485)
      WRITE(4,385) XMIN
      IF(IRW.EQ.2) WRITE(1,435) XMIN
      WRITE(4,495)
      WRITE(4,385) XMAX
      IF(IRW.EQ.2) WRITE(1,435) XMAX
111         IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,475)
120         READ(IRLUN,105) LEN,ANS
      IF(LEN.EQ.0) ANS='N'
      IF(ANS.EQ.YES.OR.ANS.EQ.NO) GO TO 130
      WRITE(5,155)
      GO TO 120
130         IF(ANS.EQ.YES) IYMM=1
      IF(IYMM.EQ.0) GO TO 170
      IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,485)
140         READ(IRLUN,*,ERR=150) YMIN
      GO TO 160
150         WRITE(5,155)
      GO TO 140
160         IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,495)
      READ(IRLUN,*) YMAX
170         WRITE(4,475)
      WRITE(4,265) ANS
      IF(IRW.EQ.2) WRITE(1,585) ANS
      IF(ANS.EQ.NO) GO TO 171
      WRITE(4,485)
      WRITE(4,385) YMIN
      IF(IRW.EQ.2) WRITE(1,435) YMIN
      WRITE(4,495)
      WRITE(4,385) YMAX
      IF(IRW.EQ.2) WRITE(1,435) YMAX
171         IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,555) ESC,HOME,ESC,CLR
      IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,125)
```

```
350       IF(ANS.EQ.YES) ISCX=1
  WRITE(4,245)
  WRITE(4,355) ISCL
  WRITE(4,255)
  WRITE(4,195)
  WRITE(4,275) XLEN
  IF(IRW.EQ.2) WRITE(1,425) XLEN
  WRITE(4,205)
  WRITE(4,275) XBLINT
  IF(IRW.EQ.2) WRITE(1,425) XBLINT
  WRITE(4,185)
  WRITE(4,265) ANS
  IF(IRW.EQ.2) WRITE(1,585) ANS
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,555) ESC,HOME,ESC,CLR
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,355) ISCL
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,375)
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,215)
360       READ(IRLUN,*,ERR=370) YLEN
  IF(YLEN.GE.1..AND.YLEN.LE.10.) GO TO 380
370       WRITE(5,155)
  GO TO 360
380       IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,205)
390       READ(IRLUN,*,ERR=400) YBLINT
  IF(YBLINT.LE.0..OR.YBLINT.GT.YLEN) GO TO 400
  GO TO 410
400       WRITE(5,155)
  GO TO 390
410       IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,185)
420       READ(IRLUN,105) LEN,ANS
  IF(LEN.EQ.0) ANS='N'
  IF(ANS.EQ.YES.OR.ANS.EQ.NO) GO TO 430
  WRITE(5,155)
  GO TO 420
430       IF(ANS.EQ.YES) ISCY=1
  WRITE(4,245)
  WRITE(4,355) ISCL
  WRITE(4,375)
  WRITE(4,215)
  WRITE(4,275) YLEN
  IF(IRW.EQ.2) WRITE(1,425) YLEN
  WRITE(4,205)
  WRITE(4,275) YBLINT
  IF(IRW.EQ.2) WRITE(1,425) YBLINT
  WRITE(4,185)
  WRITE(4,265) ANS
  IF(IRW.EQ.2) WRITE(1,585) ANS
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,555) ESC,HOME,ESC,CLR
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,355) ISCL
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,95)
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,225)
440       READ(IRLUN,455,ERR=450) LEN,IPSCL
  IF(LEN.EQ.0) IPSCL=1
  IF(IPSCL.GT.0.AND.IPSCL.LT.4) GO TO 460
450       WRITE(5,155)
  GO TO 440
```

--APPENDIX E--

```
 IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,365)
180       READ(IRLUN,405,ERR=190) IC
 IF(IC.EQ.1.OR.IC.EQ.2.OR.IC.EQ.3) GO TO 200
190       WRITE(5,155)
 GO TO 180
200       IF(IC.NE.1) GO TO 210
 NTYPE=0
 GO TO 250
210       IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,395)
220       READ(IRLUN,405,ERR=230) NCYCLE
 IF(NCYCLE.GE.1) GO TO 240
230       WRITE(5,155)
 GO TO 220
240       IF(IC.EQ.2) NTYPE=NCYCLE
 IF(IC.EQ.3) NTYPE=-NCYCLE
250       WRITE(4,245)
 WRITE(4,125)
 WRITE(4,365)
 WRITE(4,285) IC
 IF(IRW.EQ.2) WRITE(1,405) IC
 IF(IC.EQ.1) GO TO 251
 WRITE(4,395)
 WRITE(4,285) NCYCLE
 IF(IRW.EQ.2) WRITE(1,405) NCYCLE
251       IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,165)
260       READ(IRLUN,105) LEN,ANS
 IF(LEN.EQ.0) ANS='N'
 IF(ANS.EQ.YES.OR.ANS.EQ.NO) GO TO 270
 WRITE(5,155)
 GO TO 260
270       IF(ANS.EQ.YES) IRT=5
 IF(ANS.EQ.NO) IRT=1
 WRITE(4,165)
 WRITE(4,265) ANS
 IF(IRW.EQ.2) WRITE(1,585) ANS
 IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,555) ESC,HOME,ESC,CLR
 IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,355) ISCL
 IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,255)
 IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,195)
280       READ(IRLUN,*,ERR=290) XLEN
 IF(XLEN.GE.1.) GO TO 300
290       WRITE(5,155)
 GO TO 280
300       IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,205)
310       READ(IRLUN,*,ERR=320) XBLINT
 IF(XBLINT.LE.0..OR.XBLINT.GT.XLEN) GO TO 320
 GO TO 330
320       WRITE(5,155)
 GO TO 310
330       IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,185)
340       READ(IRLUN,105) LEN,ANS
 IF(LEN.EQ.0) ANS='N'
 IF(ANS.EQ.YES.OR.ANS.EQ.NO) GO TO 350
 WRITE(5,155)
 GO TO 340
```

--APPENDIX E--

```
460       IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,565)
470       READ(IRLUN,575,ERR=480) LEN,ASIZE
  IF(LEN.EQ.0) ASIZE=.1
  IF(ASIZE.LT..07.OR.ASIZE.GT..5) GO TO 480
  GO TO 490
480       WRITE(5,155)
  GO TO 470
490       WRITE(4,245)
  WRITE(4,355) ISCL
  WRITE(4,95)
  WRITE(4,225)
  WRITE(4,285) IPSCL
  IF(IRW.EQ.2) WRITE(1,405) IPSCL
  WRITE(4,565)
  WRITE(4,275) ASIZE
  IF(IRW.EQ.2) WRITE(1,595) ASIZE
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,555) ESC,HOME,ESC,CLR
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,355) ISCL
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,445)
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,315)
500       READ(IRLUN,325) NXTL,XTL
  IF(NXTL.GT.40) GO TO 510
  IF(IRW.EQ.2.AND.NXTL.EQ.0) WRITE(1,585)
  IF(NXTL.EQ.0) GO TO 589
  GO TO 520
510       IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,15)
  GO TO 500
520       IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,565)
530       READ(IRLUN,575,ERR=540) LEN,XSIZE
  IF(LEN.EQ.0) XSIZE=.2
  IF(XSIZE.LT..07.OR.XSIZE.GT..5) GO TO 540
  GO TO 550
540       WRITE(5,155)
  GO TO 530
550       IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,225)
560       READ(IRLUN,455,ERR=570) LEN,IPXTL
  IF(LEN.EQ.0) IPXTL=1
  IF(IPXTL.GT.0.AND.IPXTL.LT.4) GO TO 580
570       WRITE(5,155)
  GO TO 560
580       WRITE(4,245)
  WRITE(4,445)
  WRITE(4,315)
  WRITE(4,305) (XTL(I),I=1,NXTL)
  IF(IRW.EQ.2) WRITE(1,585) (XTL(I),I=1,NXTL)
  WRITE(4,565)
  WRITE(4,275) XSIZE
  IF(IRW.EQ.2) WRITE(1,595) XSIZE
  WRITE(4,225)
  WRITE(4,285) IPXTL
  IF(IRW.EQ.2) WRITE(1,405) IPXTL
589       IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,335)
590       READ(IRLUN,325) NYTL,YTL
  IF(NYTL.GT.40) GO TO 600
  IF(IRW.EQ.2.AND.NYTL.EQ.0) WRITE(1,585)
```

--APPENDIX E--

```
      IF(NYTL.EQ.0) GO TO 676
      GO TO 610
600        IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,15)
      GO TO 590
610        IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,565)
620        READ(IRLUN,575,ERR=630) LEN,YSIZE
      IF(LEN.EQ.0) YSIZE=.2
      IF(YSIZE.LT..07.OR.YSIZE.GT..5) GO TO 630
      GO TO 640
630        WRITE(5,155)
      GO TO 620
640        IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,225)
650        READ(IRLUN,455,ERR=660) LEN,IPYTL
      IF(LEN.EQ.0) IPYTL=1
      IF(IPYTL.GT.0.AND.IPYTL.LT.4) GO TO 670
660        WRITE(5,155)
      GO TO 650
670        WRITE(4,335)
      WRITE(4,305) (YTL(I),I=1,NYTL)
      IF(IRW.EQ.2) WRITE(1,585) (YTL(I),I=1,NYTL)
      WRITE(4,565)
      WRITE(4,275) YSIZE
      IF(IRW.EQ.2) WRITE(1,595) YSIZE
      WRITE(4,225)
      WRITE(4,285) IPYTL
      IF(IRW.EQ.2) WRITE(1,405) IPYTL
676        IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,555) ESC,HOME,ESC,CLR
      WRITE(4,245)
      DO 780 I=1,4
      IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,345) I
      ISTRT=(I-1)*60+1
      IEND=ISTRT+59
680        READ(IRLUN,325) NTTL(I),(TTL(J),J=ISTRT,IEND)
      IF(NTTL(I).GT.60) GO TO 690
      IF(IRW.EQ.2.AND.NTTL(I).EQ.0) WRITE(1,585)
      IF(NTTL(I).EQ.0) GO TO 780
      GO TO 720
690        IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,15)
      GO TO 680
720        IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,235)
730        READ(IRLUN,575,ERR=740) LEN,TSIZE(I)
      IF(LEN.EQ.0) TSIZE(I)=.2
      IF(TSIZE(I).LT..07.OR.TSIZE(I).GT..5) GO TO 740
      GO TO 750
740        WRITE(5,155)
      GO TO 730
750        IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,175)
760        READ(IRLUN,455,ERR=770) LEN,IPTTL(I)
      IF(LEN.EQ.0) IPTTL(I)=1
      IF(IPTTL(I).GT.0.AND.IPTTL(I).LT.4) GO TO 771
770        WRITE(5,155)
      GO TO 760
771        WRITE(4,345) I
      JEND=ISTRT+NTTL(I)-1
      IF(NTTL(I).GT.0) WRITE(4,295) (TTL(J),J=ISTRT,JEND)
```

```
  IF(IRW.EQ.2) WRITE(1,585) (TTL(J),J=ISTRT,JEND)
  WRITE(4,235)
  WRITE(4,275) TSIZE(I)
  IF(IRW.EQ.2) WRITE(1,595) TSIZE(I)
  WRITE(4,175)
  WRITE(4,285) IPTTL(I)
  IF(IRW.EQ.2) WRITE(1,405) IPTTL(I)
780       CONTINUE
  WRITE(5,555) ESC,HOME,ESC,CLR
  NDIG1=2
  NDIG2=2
  IF(ISCL.LT.10) NDIG1=1
  IF(ICRV.LT.10) NDIG2=1
  WRITE(5,355) ISCL
  WRITE(5,45) ISCL
  IFNS=(ISCL-1)*12+1
  IFNE=ISCL*12
790       READ(5,55) LEND,(DNAME(I),I=IFNS,IFNE)
  LENDE=IFNS+LEND
  DNAME(LENDE)=0
  CALL ERRTST(29,K)
  OPEN (UNIT=3,NAME=DNAME(IFNS),READONLY,TYPE='OLD',ERR=800)
  CALL ERRTST(29,K)
  IF(K.EQ.2) GO TO 810
800       WRITE(5,155)
  GO TO 790
810       WRITE(4,245)
  WRITE(4,355) ISCL
  WRITE(4,45) ISCL
  WRITE(4,305) (DNAME(I),I=IFNS,IFNE)
  DO 820 I=1,24
  READ(3,55) LEN,T
820       CONTINUE
  NOE(1)=0
  I=1
830       READ(3,5) LEN,XY1(I)
  IF(LEN.EQ.0) GO TO 840
  NOE(1)=NOE(1)+1
  I=I+1
  GO TO 830
840       NOE(1)=NOE(1)-1
  IF(NOE(1).LE.1000) GO TO 850
  IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,75)
  GO TO 9999
850       DO 860 I=1,11
  READ(3,55) LEN,T
860       CONTINUE
  NOE(2)=1
  I=1
870       READ(3,5,END=880) LEN,XY2(I)
  NOE(2)=NOE(2)+1
  I=I+1
  GO TO 870
880 .     NOE(2)=NOE(2)-1
  REWIND 3
```

```
      DO 890 I=1,24
      READ(3,55) LEN,T
890        CONTINUE
      DO 900 I=1,NOE(1)
      READ(3,*) LEN,XY1(I)
900        CONTINUE
      DO 910 I=1,12
      READ(3,55) LEN,T
910        CONTINUE
      DO 920 I=1,NOE(2)
      READ(3,*) LEN,XY2(I)
920        CONTINUE
      CLOSE (UNIT=3)
      NOE(1)=NOE(1)/2
      NOE(2)=NOE(2)/2
      XMINT=1.E27
      YMINT=1.E27
      XMAXT=1.E-27
      YMAXT=1.E-27
      DO 930 I=1,NOE(1)
      IF(XY1(I).LT.XMINT) XMINT=XY1(I)
      IF(XY1(I).GT.XMAXT) XMAXT=XY1(I)
      IF(XY1(NOE(1)+I).LT.YMINT) YMINT=XY1(NOE(1)+I)
      IF(XY1(NOE(1)+I).GT.YMAXT) YMAXT=XY1(NOE(1)+I)
930        CONTINUE
      DO 940 I=1,NOE(2)
      IF(XY2(I).LT.XMINT) XMINT=XY2(I)
      IF(XY2(I).GT.XMAXT) XMAXT=XY2(I)
      IF(XY2(NOE(2)+I).LT.YMINT) YMINT=XY2(NOE(2)+1)
      IF(XY2(NOE(2)+I).GT.YMAXT) YMAXT=XY2(NOE(2)+1)
940        CONTINUE
      IF(IXMM.EQ.1) GO TO 950
      XMIN=XMINT
      XMAX=XMAXT
950        IF(IYMM.EQ.1) GO TO 960
      YMIN=YMINT
      YMAX=YMAXT
960        WRITE(4,245)
      DO 990 ICRV=1,2
      IF(ICRV.EQ.1.AND.(IRW.EQ.2.OR.IRW.EQ.3)) WRITE(5,135)
      IF(ICRV.EQ.2.AND.(IRW.EQ.2.OR.IRW.EQ.3)) WRITE(5,145)
      IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,225)
970        READ(IRLUN,455,ERR=980) LEN,IPCRV(ICRV)
      IF(LEN.EQ.0) IPCRV(ICRV)=1
      IF(IPCRV(ICRV).GT.0.AND.IPCRV(ICRV).LT.4) GO TO 981
980        WRITE(5,155)
      GO TO 970
981        IF(ICRV.EQ.1) WRITE(4,135)
      IF(ICRV.EQ.2) WRITE(4,145)
      WRITE(4,225)
      WRITE(4,285) IPCRV(ICRV)
      IF(IRW.EQ.2) WRITE(1,405) IPCRV(ICRV)
990        CONTINUE
      IF(IRW.EQ.2.OR.IRW.EQ.3) WRITE(5,555) ESC,HOME,ESC,CLR
      XQIBB=XBLINT/.25
```

--APPENDIX E--

```
      YQIBB=YBLINT/.25
      CALL BGNSTP(NTYPE,-2,OMIT,0,1)
      IF(ISCX.EQ.0) GO TO 1000
      CALL BOPTMM(XMIN,XMAX,XLEN,XQIBB)
 1000       IF(ISCY.EQ.0) GO TO 1010
      CALL BOPTMM(YMIN,YMAX,YLEN,YQIBB)
 1010       CALL NEWPEN(IPSCL)
      DO 1020 JPI=1,IRT
      FJ=FLOAT(JPI-1)
      TPA=6.2831853E0*FJ/5.
      AX=.008*COS(TPA)
      AY=.008*SIN(TPA)
      IF(IRT.EQ.1) AX=0.0
      IF(IRT.EQ.1) AY=0.0
      CALL PLOT(AX,AY,-3)
      CALL BGNSCL(ISCL,XMIN,XMAX,YMIN,YMAX,0,0,
     1   XLEN,XBLINT,YLEN,YBLINT,1.5,1.,1.5,1.,ASIZE)
 1020       CONTINUE
      RXXTL=(XLEN-(NXTL*XSIZE))/2.+1.5
      RYXTL=1.0-(XTLRY+(1.5*XSIZE))
      RXYTL=1.5-(YTLRX+(.5*YSIZE))
      RYYTL=(YLEN-(NYTL*YSIZE))/2.+1.
      RYTTL(4)=YLEN+1.2
      RYTTL(3)=RYTTL(4)+1.5*TSIZE(4)
      RYTTL(2)=RYTTL(3)+1.5*TSIZE(3)
      RYTTL(1)=RYTTL(2)+1.5*TSIZE(2)
      CALL NEWPEN(IPTTL)
      DO 1040 I=1,4
      DO 1040 JPI=1,IRT
      FJ=FLOAT(JPI-1)
      TPA=6.2831853E0*FJ/5.
      AX=.008*COS(TPA)
      AY=.008*SIN(TPA)
      IF(IRT.EQ.1) AX=0.0
      IF(IRT.EQ.1) AY=0.0
      CALL PLOT(AX,AY,-3)
      IF(NTTL(I).EQ.0) GO TO 1040
      IL=(I-1)*60+1
      CALL BGNTTL(TTL(IL),NTTL(I),TSIZE(I),2.,RYTTL(I),1.,0.)
 1040       CONTINUE
      IF(NYTL.EQ.0) GO TO 1051
      CALL NEWPEN(IPYTL)
      DO 1050 JPI=1,IRT
      FJ=FLOAT(JPI-1)
      TPA=6.2831853E0*FJ/5.
      AX=.008*COS(TPA)
      AY=.008*SIN(TPA)
      IF(IRT.EQ.1) AX=0.0
      IF(IRT.EQ.1) AY=0.0
      CALL PLOT(AX,AY,-3)
      CALL BGNTTL(YTL,NYTL,YSIZE,RXYTL,RYYTL,1.,90.)
 1050       CONTINUE
 1051       IF(NXTL.EQ.0) GO TO 1061
      CALL NEWPEN(IPXTL)
      DO 1060 JPI=1,IRT
```

```
      FJ=FLOAT(JPI-1)
      TFA=6.2831853E0*FJ/5.
      AX=.008*COS(TFA)
      AY=.008*SIN(TFA)
      IF(IRT.EQ.1) AX=0.0
      IF(IRT.EQ.1) AY=0.0
      CALL PLOT(AX,AY,-3)
      IF(NXTL.EQ.0) GO TO 1060
      CALL BGNTTL(XTL,NXTL,XSIZE,RXXTL,RYXTL,1.,0.)
1060        CONTINUE
1061        RXTTL3=XLEN+3.
      CALL NEWPEN(IPXTL)
      DO 1070 JPI=1,IRT
      FJ=FLOAT(JPI-1)
      TFA=6.2831853E0*FJ/5.
      AX=.008*COS(TFA)
      AY=.008*SIN(TFA)
      IF(IRT.EQ.1) AX=0.0
      IF(IRT.EQ.1) AY=0.0
      CALL PLOT(AX,AY,-3)
      CALL BGNTTL(TTL3,15,.14,RXTTL3,4.0,1.,0.)
      CALL BGNTTL(TTL4,20,.14,RXTTL3,3.7,1.,0.)
      CALL SYMBOL(RXTTL3,4.07,.14,1,0.0,-1)
      CALL SYMBOL(RXTTL3,3.77,.14,24,0.0,-1)
1070        CONTINUE
      CALL NEWPEN(IPCRV(1))
      DO 1080 JPI=1,IRT
      FJ=FLOAT(JPI-1)
      TFA=6.2831853E0*FJ/5.
      AX=.008*COS(TFA)
      AY=.008*SIN(TFA)
      IF(IRT.EQ.1) AX=0.0
      IF(IRT.EQ.1) AY=0.0
      CALL PLOT(AX,AY,-3)
      CALL BPLOT(ISCL,NOE(1),0,XY1,XY1(NOE(1)+1),1,0.,
     1  1,SYMB,.14)
      CALL BOVPLT(ISCL)
1080        CONTINUE
      CALL NEWPEN(1)
      CALL NEWPEN(IPCRV(2))
      DO 1090 JPI=1,IRT
      FJ=FLOAT(JPI-1)
      TFA=6.2831853E0*FJ/5.
      AX=.008*COS(TFA)
      AY=.008*SIN(TFA)
      IF(IRT.EQ.1) AX=0.0
      IF(IRT.EQ.1) AY=0.0
      CALL PLOT(AX,AY,-3)
      CALL BPLOT(ISCL,NOE(2),1,XY2,XY2(NOE(2)+1),1,0.,
     1  0,0.,0.)
      CALL BOVPLT(ISCL)
1090        CONTINUE
      CALL NEWPEN(1)
      CALL ENDPLT(0)
            IF(IRM.EQ.1.OR.IRM.EQ.2) CALL CLOSE (1)
```

```
      CALL CLOSE (2)
      CALL CLOSE (4)
  WRITE(5,555) ESC,HOME,ESC,CLR
  WRITE(5,35)
1100      READ(5,105) LEN,ANS
  IF(LEN.EQ.0) ANS='N'
  IF(ANS.EQ.YES.OR.ANS.EQ.NO) GO TO 1110
  WRITE(5,155)
  GO TO 1100
1110    CONTINUE
  IF(ANS.EQ.YES) GO TO 11
  CALL NEWPEN(1)
  CALL ENDPLT(1)
  WRITE(5,555) ESC,HOME,ESC,CLR
  WRITE(5,25)
9999      CALL EXIT
5 FORMAT(Q,53X,F14.11)
15        FORMAT(' You must enter 60 characters or less.')
25        FORMAT(///////////,29X,'Successful completion.',///////////)
35        FORMAT(///////////,' Create another graph [Y/N]? ',$)
45        FORMAT(/,' Input file for Graph ',I<NDIG>,' [filespec]? ',$)
55        FORMAT(Q,13A1)
65        FORMAT(///,' Output file [filespec]? ',$)
75        FORMAT(//,' Your data file contains more than 1000 X/Y'
     1  ' coordinates.',//,' Program stop. No output produced.')
85        FORMAT(I4)
95        FORMAT('+: X and Y axes specifications:')
105       FORMAT(Q,1A1)
115       FORMAT(' That file does not exist.')
125       FORMAT(//,' Plot specifications:')
135       FORMAT(//,' ''Actual data'' curve.')
145       FORMAT(/,' ''Estimated values'' curve.')
155       FORMAT(' What!? ',$)
165       FORMAT(/,' Retrace option [Y/N]? ',$)
175       FORMAT(' [1] BLACK    [2] RED    [3] GREEN',/,
     1  ' Color? ',$)
185       FORMAT(/,' Scale option [Y/N]? ',$)
195       FORMAT(/,' X-Axis length in inches? ',$)
205       FORMAT(/,' Distance between blips in inches? ',$)
215       FORMAT(/,' Y-Axis length in inches? ',$)
225       FORMAT(/,' [1] BLACK    [2] RED    [3] GREEN',/,
     1  ' Color? ',$)
235       FORMAT(' Character SIZE in inches [.07-.5]? ',$)
245       FORMAT(/,' ----------------------------------------',
     1  '-----------------------------------',/)
255       FORMAT('+: X axis specifications:',/)
265       FORMAT('+',1A1)
275       FORMAT('+',F15.7)
285       FORMAT('+',I11)
295       FORMAT(' ',60A1)
305       FORMAT('+',40A1)
315       FORMAT(' X-Axis Title [1-40 chars.]? ',$)
325       FORMAT(Q,60A1)
335       FORMAT(/,' Y-Axis Title [1-40 chars.]? ',$)
345       FORMAT(' Graph title (line ',I1,') [1-60 chars.]? ')
```

```
355       FORMAT(' Graph number ',I<NDIG>,$)
365       FORMAT(/,' [1] Linear    [2] Semi-log    [3] Log-log'
    1  ,/,' Type of scale? ',$)
375       FORMAT('+: Y axis specifications:',/)
385       FORMAT('+',E15.7)
395       FORMAT(/,' Number of cycles [>0]? ',$)
405       FORMAT(I1)
415       FORMAT(' [1] Read responses from GRAPH1.COM ',/,
    1          '     and do not update GRAPH1.COM.',//,
    2          ' [2] Read responses from keyboard and',/,
    3          '     update GRAPH1.COM.',//,
    4          ' [3] Read responses from keyboard and',/,
    5          '     do not update GRAPH1.COM.',//,' Option? ',$)
425       FORMAT(F15.7)
435       FORMAT(E15.7)
445       FORMAT('+ Title specifications:',/)
455       FORMAT(Q,I1)
465       FORMAT(/,' X-Axis minimum/maximum overide option [Y/N]? ',$)
475       FORMAT(/,' Y-Axis minimum/maximum overide option [Y/N]? ',$)
485       FORMAT(' Minimum value? ',$)
495       FORMAT(' Maximum value? ',$)
555       FORMAT(' ',4A1)
565       FORMAT(/,' Character size in inches [.07-.5]? ',$)
575       FORMAT(Q,F5.4)
585       FORMAT(60A1)
595       FORMAT(F5.3)
  END
  SUBROUTINE BOPTMM(XMIN,XMAX,AXLEN,QIBB)
C-----------------------------------------------------------------------
------
C BOPTMM will determine a scale for plotting values between XMIN and XMAX
C such that each 1/20th inch tic mark has an easily READ decimal value.
C If QIBB specifies tic marks on the axis, '0.' must fall on a blip even
C if off the plot page.  AXLEN is truncated to the nearest 1/20th inch and
C XMIN and XMAX are changed to the endpoints of the axis to be drawn.
C
C         Arguments:
C
C         XMIN  = Minimum value in array to be plotted.
C
C         XMAX  = Maximum value in array to be plotted.
C
C         AXLEN = Axis length in inches.
C
C         QIBB  = Number of quarter inches between tic marks on axis.
C
C                 If QIBB is positive [>0] - fit scale to XMIN and XMAX
C                                            using tic mark interval.
C
C                 If QIBB is negative [<0] - permit a 2.5% overscale on
C                                            either end using tic marks.
C
C-----------------------------------------------------------------------
------
  REAL*8 XLOW,XHI,POWER
```

```
      IXHI =IXHI /10
      FXMAX=FXMAX/10.
      IEXP=IEXP+1
      GO TO 120
130       IF (IZ.EQ.0) GO TO 140
      IX=IABS(IXLOW-10*(IXLOW/10))
      IF (IX.EQ.0) GO TO 140
      IF (IXLOW.LT.0) IX=10-IX
      IL=IXHI-IX
      IF (FXMAX.GT.IL)GO TO 140
      IXHI=IL
      IXLOW=IXLOW-IX
      GO TO 120
140       POWER=10.D0**IEXP
      XLOW=IXLOW*POWER
      XHI =IXHI *POWER
      IF (RANGE.LT.0.) GO TO 150
      XMIN=XLOW
      XMAX=XHI
      RETURN
150       XMIN=XHI
      XMAX=XLOW
      RETURN
5   FORMAT(' Invalid BOPTMM arguments:',//,
     1  '     Minimum value  = ',F14.7,/,
     2  '     Maximum value  = ',F14.7,/,
     3  '     Axis length    = ',F14.7,/,
     4  '     Blip intervals = ',F14.7,//,' Program stop.')
      END
```

--APPENDIX E--

```
  IZ=0
  RANGE=XMAX-XMIN
  IF (RANGE.NE.0.) GO TO 10
  IF(IRW.EQ.2) WRITE(5,5) XMIN,XMAX,AXLEN,QIBB
  CALL EXIT
10        R=ABS(RANGE)
  IF (RANGE.GT.0.) GO TO 20
  X=XMIN
  XMIN=XMAX
  XMAX=X
20        AXL20=INT(AXLEN*20.)
  AXLEN=AXL20/20.
  UNP20=R/AXL20
  IF (QIBB.GT.0.) GO TO 30
  X=.025*R
  XMAX=XMAX-X
  XMIN=XMIN+X
  R=XMAX-XMIN
  UNP20=R/AXL20
30        TWPBLP=INT(ABS(QIBB))*5
  IF (TWPBLP.EQ.0.) GO TO 40
  IF (AXL20/TWPBLP.GT.1.0001) GO TO 50
  IF (R.LE.ABS(XMAX+XMIN)) GO TO 50
40        TWPBLP=1.
  IZ=1
50        IEXP=-1
  IF (UNP20.GE.1.) IEXP=9
60        X=0.
  Y1=10.**IEXP
70        X=X+1.
  FUNP20=X*Y1
  IF (UNP20.GT.FUNP20) GO TO 70
  IF (X.NE.1.) GO TO 80
  IF (UNP20.EQ.FUNP20) GO TO 80
  IEXP=IEXP-1
  GO TO 60
80        IX=X
  IAXL20=AXL20
  ITWPBL=TWPBLP
  FXMAX=XMAX/Y1
90        IUNPBL=ITWPBL*IX
  Y=XMIN/(IUNPBL*Y1)
  IY=Y
  IF (Y.EQ.IY) GO TO 100
  IF (Y.LT.0.) IY=IY-1
100       IXLOW=IY*IUNPBL
  IXHI=IXLOW+IAXL20*IX
  IF (FXMAX.LE.IXHI) GO TO 110
  IX=IX+1
  GO TO 90
110       IL=IUNPBL*INT((FLOAT(IXHI)-FXMAX)/(2*IUNPBL))
  IXLOW=IXLOW-IL
  IXHI =IXHI -IL
120       IF (10*(IXLOW/10).NE.IXLOW.OR.10*(IXHI/10).NE.IXHI) GO TO 130
  IXLOW=IXLOW/10
```

APPENDIX F:

CALCOMP Generated Plot (Semilogarithmic) of the GRPHX.XXX Data

--APPENDIX F--

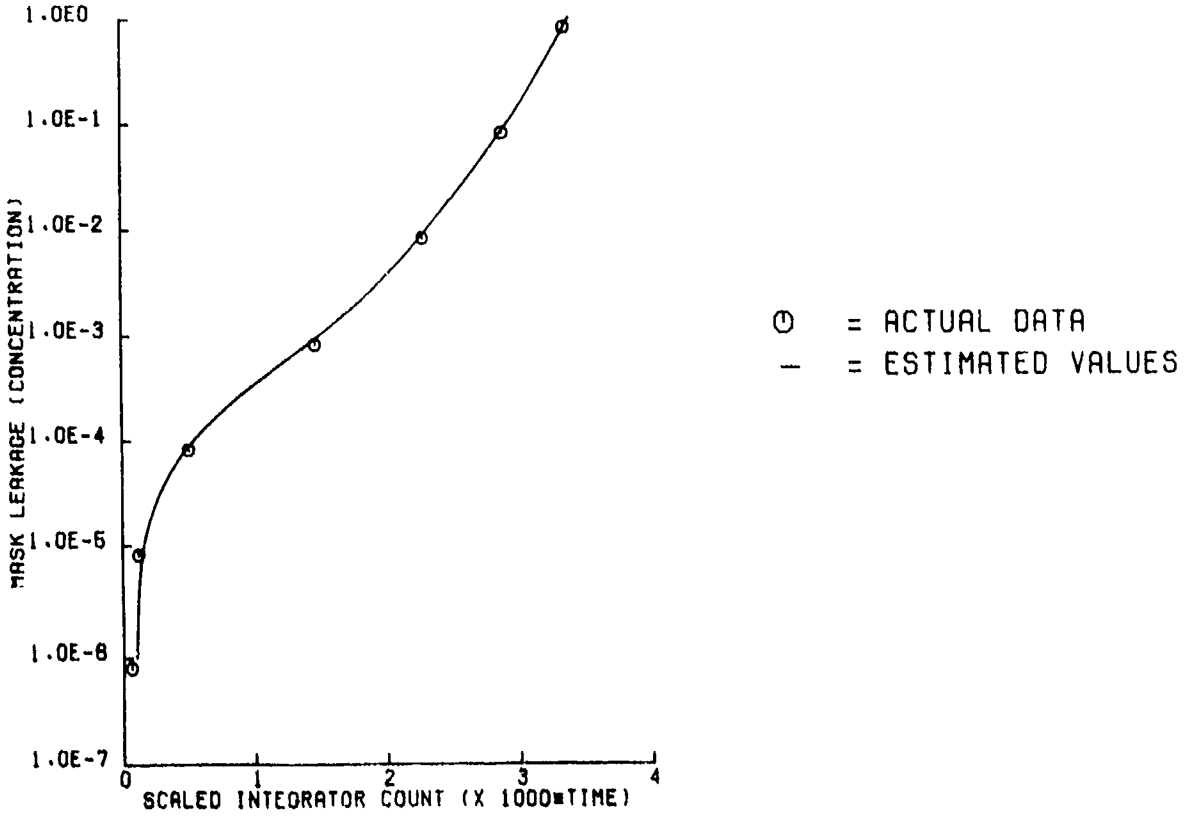

Figure F-1. Sodium chloride RQFT calibration curve mask leakage (concentration) vs. scaled integrator count.

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APPENDIX G:

User's Guide for the NACLRQFT.FTN Computer Program

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--APPENDIX G--

RESPIRATOR QUANTITATIVE FIT TESTING

INSTRUCTIONS FOR USING THE COMPUTER TERMINALS IN USAFSAM/VN TO PROCESS THE DATA COLLECTED ON THE SALT FOG INSTRUMENT

KEY: – COMPUTER GENERATED INFORMATION (CRT SCREEN)

– *Program User Generated Information (Entered via the keyboard; information displayed on the CRT screen)*

– Sequential Step Numbers; not displayed on CRT screen

– Comments to help the program user

CRT SCREEN DISPLAY	COMMENT
1) > _	CRT display status normally found on an idle terminal.
2) > *HELLO* _	Type in 'HELLO'; depress "Return" key on keyboard.
3) ACCOUNT OR NAME: _	Computer response.
4) ACCOUNT OR NAME: XXXXXX_	Type in your last name; depress "Return" key on keyboard.
5) PASSWORD: _	Computer response.
6) PASSWORD: XXXX _	Type in your password; password characters are not displayed on CRT screen; depress "Return" key on keyboard.
. . . . (SERIES OF COMPUTER SYSTEM MESSAGES)	No response required on your part.
ENTER TERMINAL TRACKING NUMBER (WHITE TAG ON RIGHT FRONT)? _	Last message of the group.

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CRT SCREEN DISPLAY	COMMENT
7) ENTER TERMINAL NUMBER (WHITE TAG ON RIGHT FRONT)? XX _	Enter two digits; depress "Return" key on keyboard.
. . . (SERIES OF COMPUTER SYSTEM MESSAGES) . . .	No response required on your part.
>_	Computer is ready.
8) > *Run DR3:[305,4]NACLRQFT* _	Type in "Run DR3:[305,4]NACLRQFT; depress the "Return" key on the keyboard.
. . . (PROGRAM STATEMENTS) . . .	No response required on your part
9) ENTER THE FOLLOWING: 001 FOR THE FIRST DATA SET; 002 FOR THE SECOND DATA SET; 003 FOR THE THIRD DATA SET, ETC.	Last of program statements.
10) ENTRY = XXX _	Enter a three digit number to name this set of data. Depress the "Return" key on keyboard.
11) . . . (PROGRAM STATEMENTS) . . .	No response required on your part.
12) ENTER THE FOLLOWING: 001 FOR THE FIRST RESIDUAL SET; 002 FOR THE SECOND RESIDUAL SET; 003 FOR THE THIRD, ETC.	Last of program statements.
13) ENTRY = XXX _ . . .	Enter a three digit number to name this set of residuals; depress the "Return" key on the keyboard.

CRT SCREEN DISPLAY	COMMENT
14) . . . (PROGRAM STATEMENTS) . . .	No response required on your part.
15) ENTER THE FOLLOWING 001 FOR THE FIRST GRAPH SET; 002 FOR THE SECOND GRAPH SET; 003 FOR THE THIRD, ETC.	Last of program statements.
16) ENTRY = XXX _	Enter a three digit number to name this graph set; depress the "Return" key on the keyboard.
17) ENTER THE NUMBER OF SODIUM CHLORIDE CALIBRATION CONCENTRATION STANDARDS. ENTRY = 7 _	There are seven sodium chloride calibration concentration standards. Enter the number '7'; depress the "Return" key on the keyboard.
18) DEPRESS RETURN KEY AFTER A VOLTAGE MEASUREMENT	No response required on your part.
19) ENTER THE DATA POINTS	Enter a voltage measurement, then depress the "Return" key on the keyboard. Type the corresponding sodium chloride calibration concentration then depress the "Return" key on the keyboard. Repeat this procedure until all data points have been entered.

SAMPLE NUMBER	VOLTAGE MEASUREMENT (X DATA)	SODIUM CHLORIDE CONCENTRATION (Y DATA)
1	XXX	1.0
2	XXX	0.1
3	XXX	0.01
4	XXX	0.001
5	XXX	0.0001
6	XXX	0.00001
7	XXX	0.000001

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CRT SCREEN DISPLAY	COMMENT
20) SUBJECT NAME: _XXXXX_	Enter subject's name (up to 30 characters long); depress the "Return" key on the keyboard.
21) TYPE OF MASK: _XXXXX_	Enter mask nomenclature (up to 30 characters long), depress "Return" key on keyboard.
22) DATE TESTED: _XXXXX_	Enter date subject was tested; depress the "Return" key on the keyboard.
23) TIME TESTED: _XXXXX_	Enter the time of day subject was tested (for Example: 1430 hours); depress "Return" key on keyboard.
24) THE USER IS FREE TO SELECT ONE OF TWO GROUPS OF EXERCISE PROTOCOLS. . . . (PROGRAM STATEMENTS) . . .	First of a series of program statements explaining the two groups of exercises. No response required on your part.
25) TO SPECIFY THE EXERCISE PROTOCOL GROUP OF INTEREST, TYPE EITHER: GROUP 1 OR GROUP 2	Last of program statements.
ENTRY = *Group X* _ . . .	Enter either 'Group 1' or 'Group 2'; depress the "Return" key on the keyboard.
26) . . . . (PROGRAM STATEMENTS) . . .	The program statements explain how to enter integrator data. No response on your part.

CRT SCREEN DISPLAY	COMMENT
27) EXERCISE COUNT DATA: EXERCISE — INTEGRATOR COUNT — TIME PERIOD (IN SECONDS) NORMAL BREATHING STRAIGHT AHEAD — _XXXXXX_ — _XX_	Enter integrator exercise count data as previously specified in the program statements; depress the "Return" key on the keyboard after each integrator count value. Enter the time period for the exercise using no decimal points; depress the "Return" key on the keyboard. Repeat until data for each exercise has been input.
28) . . . (PROGRAM STATEMENTS) . . .	The program statements explain the functional definitions of the variable (X); no response is required on your part.
29) TO SPECIFY A FUNCTIONAL DEFINITION OF (X) SELECT THE CORRESPONDING NUMBER INSIDE THE BRACKETS	Last of program statements.
ENTRY = 3_	Enter the number '3'; depress the "Return" key on the keyboard.
30) ENTER THE ORDER OF THE DESIRED POLYNOMIAL (MAXIMUM = THE NUMBER OF SODIUM CHLORIDE CALIBRATION CONCENTRATION STANDARDS -1) ENTRY = 6_	Enter the number '6'; depress the "Return" key on the keyboard.
31) . . . (PROGRAM STATEMENTS) . . .	A list of coefficient numbers is printed on the CRT screen; no response required on your part.
32) DO YOU WANT A LIST OF RESIDUALS? (ANSWER YES OR NO) _Yes_	Enter 'Yes', unless otherwise instructed; depress the "Return" key on the keyboard.

CRT SCREEN DISPLAY	COMMENT
33) . . . (PROGRAM STATEMENTS)	A list of residuals is displayed on the CRT screen. No response required on your part. If you want to stop the flow of information on the CRT screen, depress simultaneously the 'CTRL' and 'S' keys on the keyboard. To resume the flow of information on the CRT screen, depress simultaneously the 'CRTL' and 'Q' keys on the keyboard.
34) . . . (PROGRAM STATEMENTS) . . .	The descriptive and protection factor calculations are displayed on CRT screen; no response required on your part.
35) DO YOU WISH TO USE THE SAME SODIUM CHLORIDE STANDARD CALIBRATION VOLTAGE MEASUREMENTS AND EXERCISE INTEGRATOR COUNT DATA, BUT CALCULATE A DIFFERENT DEGREE OR FORM OF THE POLYNOMIAL CURVE FITTING FUNCTION? (ANSWER YES OR NO) _XXX_	Type in 'Yes' or 'No' depending upon your desires; depress the "Return" key on the keyboard. – If you type in 'No' the result will be: 36) – If you type in 'Yes' the result will be: 29)
36) DO YOU WISH TO CALCULATE PROTECTION FACTORS FOR ANY OR ALL OF THE FOLLOWING CONDITIONS: 1) A DIFFERENT SUBJECT 2) A DIFFERENT SET OF SODIUM CHLORIDE CALIBRATION STANDARD VOLTAGE MEASUREMENTS 3) A DIFFERENT SET OF EXERCISE INTEGRATOR COUNT DATA? (ANSWER YES OR NO) _XXX_	Type in: 'Yes' or 'No' depending upon your desires; depress the "Return" key on the keyboard. – If you type in 'No' the result is 37) – If you type in 'Yes' the result is 9)
37) > _ PRINT DATA.XXX_	If you want a computer print out on paper of the data that you input, type 'PRINT DATA.XXX', where XXX is the number you entered from the keyboard in step 9); depress the "Return" key on keyboard.

CRT SCREEN DISPLAY	COMMENT
38) > _PRINT CALCX.XXX_	If you want a computer print out on paper of the results, type 'PRINT CALCX.XXX', where the first X of CALCX.XXX is assigned the number 1 by the computer and incremented by 1 each time a form of the polynomial curve fitting function is calculated, and XXX is the number you entered from the keyboard in step 13); depress the "Return" key on the keyboard.
39) > _PRINT GRPHX.XXX_	If you want a computer print out on paper of the graphing data, type 'PRINT GRPHX.XXX', where the first X of GRPHX.XXX is assigned the number 1 by the computer and incremented by 1 each time a form of the polynomial curve fitting function is calculated, and XXX is the number you entered from the keyboard in step 16); depress the "Return" key on the keyboard.
40) > _BYE_	If you are finished with the computer, type in: 'BYE' from the keyboard; depress the "Return" key on keyboard and you will be automatically logged off the computer terminal. Computer printed results can be picked up in computer center, Bldg 150, approximately 2 hours after you log off the computer terminal.

APPENDIX H:

User's Guide for the NACLGRAPH.FTN Computer Program

--APPENDIX H--

2-D PLOTTING ROUTINE

INSTRUCTIONS FOR USING THE COMPUTER TERMINALS IN USAFSAM/VN TO PLOT A GRAPH IN TWO DIMENSIONS.

KEY:
- COMPUTER GENERATED INFORMATION (CRT SCREEN)
- *Program User Generated Information (Entered via the keyboard; information displayed on the CRT screen)*
- Sequential Step Numbers; not displayed on CRT screen
- **Comments to help the program user**

	CRT SCREEN DISPLAY	COMMENT
1)	> _	**CRT display status normally found on an idle terminal.**
2)	> *HELLO* _	**Type in 'HELLO'; depress "Return" key on keyboard.**
3)	ACCOUNT OR NAME: _	**Computer response.**
4)	ACCOUNT OR NAME: *XXXXXX*_	**Type in your last name; depress "Return" key on keyboard.**
5)	PASSWORD: _	**Computer response.**
6)	PASSWORD: *XXXX* _	**Type in <u>your</u> password; password characters are <u>not</u> displayed on CRT screen; depress "Return" key on keyboard.**
	. . . (SERIES OF COMPUTER SYSTEM MESSAGES) . . .	**No response required on your part.**
	ENTER TERMINAL TRACKING NUMBER (WHITE TAG ON RIGHT FRONT)? _	**Last message of the group.**

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CRT SCREEN DISPLAY	COMMENT
7) ENTER TERMINAL TRACKING NUMBER (WHITE TAG ON RIGHT FRONT)? XX_	Enter two digits; depress "Return" key on keyboard.
. . . (SERIES OF COMPUTER SYSTEM MESSAGES)	No response required on your part.
> _	Computer is ready.
8) *Run DR3:[305,4]NACLGRAPH*	Type in "Run DR3:[305,4]NACLGRAPH; depress the "Return" key on keyboard
9) "[1] READ RESPONSES FROM GRAPH1.COM'AND DO NOT UPDATE GRAPH1.COM. [2] READ RESPONSES FROM KEYBOARD AND UPDATE GRAPH1.COM. [3] READ RESPONSES FROM KEYBOARD AND DO NOT UPDATE GRAPH1.COM.	Computer response explaining the three graphing options of the program. No response required on your part.
OPTION? X_	Enter the number '1' '2' or'3'; depress the "Return" key on the keyboard. If you enter the number '2' or '3' the result is 10). If you enter the number '1' the result is 59).
10) OUTPUT FILE [FILESPEC]? XXXXXX.XXX_	Enter the name of the output file in the form 'XXXXXX.XXX'; the file name may have up to nine characters before the period and must have three characters after the period. For example, 'PLOT.001'; depress the "Return" key on the keyboard.
11) GRAPH NUMBER N X-AXIS MINIMUM/MAXIMUM OVERRIDE OPTION [Y/N]? Y_	Enter the letter 'Y'; depress the "Return" key on the keyboard.

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CRT SCREEN DISPLAY	COMMENT
12) MINIMUM VALUE? XXX_	Enter the smallest value on the X-Axis; depress the "Return" key on the keyboard.
13) MAXIMUM VALUE? XXX_	Enter the largest value on the X-axis. Depress the "Return" key on the keyboard.
14) Y-AXIS MINIMUM/MAXIMUM OVERRIDE OPTION [Y/N]? Y_	Enter the letter 'Y'; depress the "Return" key on the keyboard.
15) MINIMUM VALUE? XXX_	Enter the smallest value on the Y-axis; depress the "Return" key on the keyboard.
16) MAXIMUM VALUE? XXX_	Enter the largest value on the Y-axis; depress the "Return" key on the keyboard.
17) PLOT SPECIFICATIONS: [1] LINEAR [2] SEMI-LOG [3] LOG-LOG TYPE OF SCALE? 2_	Enter the number '2' unless otherwise instructed; depress the "Return" key on the keyboard.
18) NUMBER OF CYCLES [>0]? 7_	Enter the number '7' unless otherwise instructed; depress the "Return" key on the keyboard.
19) RETRACE OPTION [Y/N]? Y_	Enter the letter 'Y'; depress the "Return" key on the keyboard.
20) GRAPH NUMBER N: X-AXIS SPECIFICATIONS: X-AXIS LENGTH IN INCHES? XX_	Enter the length of the X-axis in inches number not a word; depress the "Re keyboard.
21) DISTANCE BETWEEN BLIPS IN INCHES? XX_	Enter the distance in in X-axis. Enter a nu "Return" key on the

CRT SCREEN DISPLAY	COMMENT
22) SCALE OPTION [Y/N]? N_	Enter the letter 'N' unless otherwise instructed; depress the "Return" key on the keyboard.
23) GRAPH NUMBER N: Y-AXIS SPECIFICATIONS: Y-AXIS LENGTH IN INCHES? XX _	Enter the length of the Y-axis in inches. Enter a number not a word; depress the "Return" key on keyboard.
24) DISTANCE BETWEEN BLIPS IN INCHES? XX_	Enter the distance in inches between points on the Y-axis. Enter a number not a word; depress the "Return" key on keyboard.
25) SCALE OPTION [Y/N]? N_	Enter the letter 'N' unless otherwise instructed; depress the "Return key on the keyboard.
26) GRAPH NUMBER N: X AND Y AXIS SPECIFICATIONS: [1] BLACK [2] RED [3] GREEN COLOR? 1_	Enter the number '1'. Depress the "Return" key on the keyboard.
27) CHARACTER SIZE IN INCHES [.07 - .5]? .XX_	Enter the size of the number to be displayed along the X and Y axis. Enter a number between 0.07 and 0.5 in inches. Depress the "Return" key on the keyboard.
28) GRAPH NUMBER N TITLE SPECIFICATIONS: X-AXIS TITLE [1-40]? XXXXX_	Type in the title for the x-axis. Limit the number of characters to 40; depress the "Return" key on the keyboard.
29) CHARACTER SIZE IN INCHES [.07-.5]? XX_	Enter the size of the characters for the X-axis title in inches. Type a number between 0.07 and 0.5; depress the "Return" key on the keyboard.
30) [1] BLACK [2] RED [3] GREEN COLOR? 1_	Enter the number '1'; depress the "Return" key on the keyboard.

CRT SCREEN DISPLAY	COMMENT
31) Y-AXIS TITLE [1-40 CHARS.]? XXXXX_	Type in the tile for the Y-axis. Limit the number of characters to 40; depress the "Return" key on the keyboard.
32) CHARACTER SIZE IN INCHES [.07-.5]? XX_	Enter the size of the characters for the Y-axis title in inches. Enter a number between 0.07 and 0.5; depress the "Return" key on the keyboard.
33) [1] BLACK [2] RED [3] GREEN COLOR? 1_	Enter the number '1'; depress the "Return" key on the keyboard.
34) GRAPH TITLE (LINE 1) [1-60 CHARCS.]? XXXXX_	Type in the first line of the graph title. Limit the number of characters to 60; depress the "Return" key on the keyboard.
35) CHARACTER SIZE IN INCHES [.07-.5]? XX_	Enter the size of the characters in the first line of the graph title in inches. Enter a number between 0.07 and 0.5; depress the "Return" key on the keyboard.
36) [1] BLACK [2] RED [3] GREEN COLOR? 1_	Enter the number '1'; depress the "Return" key on the keyboard.
37) GRAPH TITLE (LINE 2) [1-60 CHARS.]? XXXXX_	If a line of the graph title is to be centered under a preceding line, include an appropriate number of blank spaces before typing the title. Type in the second line of the graph title. Limit the number of characters to 60; depress the "Return" key on the keyboard.
38) CHARACTER SIZE IN INCHES [.07-.5]? XX_	Enter the size of the characters in the second line of the graph title in inches. Enter a number between 0.07 and 0.5; depress the "Return" key on the keyboard.

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CRT SCREEN DISPLAY	COMMENT
39) [1] BLACK [2] RED [3] GREEN COLOR? 1_	Enter the number '1'; depress the "Return" key on the keyboard.
40) GRAPH TITLE (LINE 3) [1-60 CHARS.]? XXXXX_	Type in the third line of the graph title. Limit the number of characters to 60; depress the "Return" key on the keyboard.
41) CHARACTER SIZE IN INCHES [.07-.5]? XX_	Enter the size of the characters in the third line of the graph title in inches. Enter a number between 0.07 and 0.5; depress the "Return" key on the keyboard.
42) [1] BLACK [2] RED [3] GREEN COLOR? 1_	Enter the number '1'; depress the "Return" key on the keyboard.
43) GRAPH TITLE (LINE 4) [1-60 CHARS]? XXXXX_	Type in the fourth line of the graph title. Limit the number of characters to 60; depress the "Return" key on the keyboard.
44) CHARACTER SIZE IN INCHES [.07-.5]? XX_	Enter the size of the characters in the fourth line of the graph title in inches. Enter a number between 0.07 and 0.5; depress the "Return" key on the keyboard.
45) [1] BLACK [2] RED [3] GREEN COLOR? 1_	Enter the number '1'; depress the "Return" key on the keyboard.
46) GRAPH NUMBER N INPUT FILE FOR GRAPH N [FILESPEC]? XXXXXX.XXX_	Enter the name of the input file in the form 'XXXXXX.XXX'; the file name may have up to nine characters before the period and must have three characters after the period. For example, 'GRPH1.001'; depress the "Return" key on the keyboard.

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CRT SCREEN DISPLAY	COMMENT
47) 'ACTUAL DATA' CURVE. [1] BLACK [2] RED [3] GREEN COLOR? 1_	Enter the number '1'; depress the "Return" key on the keyboard.
48) 'ESTIMATED VALUES' CURVE. [1] BLACK [2] RED [3] GREEN COLOR? 1_	Enter the number '1'; depress the "Return" key on the keyboard.
49) CREATE ANOTHER GRAPH [Y/N]? X_	Enter either the letter 'Y' or 'N'; depress the "Return" key on the keyboard.
50) SUCCESSFUL COMPLETION	Computer response. If no other graph is to be created. No response required on your part. If another graph is to be created, the computer will return to step 9) of the directions.
51) >_	Computer is ready to plot the graph on the Calcomp plotter.
52) >@OPMSG.CMD_	Enter '@OPMSG.CMD'; depress the "Return" key on the keyboard.
53) >*DISK DRX [s]: X_	Enter the disk number of the account that you signed on the terminal with; depress the "Return" key on the keyboard.
54) >*UIC XXX,XX [s]: XXX,XX_	Enter the UIC number of the account that you signed on the terminal with; use the form XXX,XX; depress the "Return" key on the keyboard.
55) >*FILENAME.EXT [s]: XXXXXX.XXX_	Enter the name of the output file for the GRAPH. Use the form 'XXXXXX.XXX'. This will be the same name as in step 10) of the directions.

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	CRT SCREEN DISPLAY	COMMENT
56)	* PLAIN/LINED [S]: *Plain*_	Enter the word 'Plain' unless otherwise instructed; depress the "Return" key on the keyboard.
	. . . (SERIES OF COMPUTER STATEMENTS) . . .	No response required on your part.
57)	>@ <EOF>	Last of computer statements; GRAPH has been created and stored.
58)	>*Bye*_	If you are finished using the computer, type in 'Bye' from the keyboard; depress the "Return" key on the keyboard and you will be automatically logged off the computer terminal.
		The GRAPH can be picked up in the computer center, Bldg 150, in approximately 3 hours.
59)	OUTPUT FILE [FILESPEC]? XXXXXX.XXX_	<u>Directions for Option 1</u>
		Enter the name of the output file in the form 'XXXXXX.XXX'; the file name may have up to nine characters before the period and must have three characters after the period. For example, 'GRAPH1.001'; depress the "return" key on the keyboard.
60)	GRAPH NUMBER N INPUT FILE FOR GRAPH N [FILESPEC]? XXXXXX.XXX_	Enter the name of the input file in the form 'XXXXXX.XXX'; the file name may have up to nine characters before the period and must have three characters after the period; depress the "Return" key on the keyboard.

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CRT SCREEN DISPLAY	COMMENT
61) CREATE ANOTHER GRAPH [Y/N]? X_	Enter the letter 'Y' or 'N'; depress the "Return" key on the keyboard. If you enter the letter 'Y' the computer goes to direction 9); if you enter the letter 'N' the computer goes to 62).
62) SUCCESSFUL COMPLETION	Computer response; no response required on your part. Computer now returns to direction 51).

ABBREVIATIONS, ACRONYMS, AND SYMBOLS

ASCC	Air Standardization Coordinating Committee
C	capacitor
C_a	ambient challenge atmosphere concentration
CDE	Chemical Defense Establishment (United Kingdom)
cm	centimeter
C_s	sampled leakage concentration
CW	chemical warfare
DB	deep breathing
dc	direct current
DTL	diode-transistor logic
E_{in}	input voltage
E_{os}	offset voltage
E_{out}	output voltage
e^x	exponential of X
FG	facial grimacing
i	current; or, the i^{th} exercise
i_s	input bias current
IC	integrator count
i.d.	inside diameter
i_{R_C}	current leakage through the integrator capacitor
ITT	International Telephone and Telegraph
K or k	kilo (1000)
kPa	kilo-Pascals
LED	light emitting diode
$\log_{10}$	logarithm to the base ten
μA	microampere
μF	microfarad
μm	micrometer
μs	microsecond
μV	microvolt
mA	milliampere
min	minute

(Cont'd. on facing page)

ABBREVIATIONS, ACRONYMS, AND SYMBOLS (Cont'd.)

ml	milliliter
MMAD	mass median aerodynamic diameter
MOD	Ministry of Defence (United Kingdom)
ms	millisecond
mV	millivolt
nA	nanoampere(s)
NaCl	sodium chloride
NATO	North Atlantic Treaty Organization
NB	normal breathing
nm	nanometer
ns	nanosecond
Ω	ohms
pF	picofarad
PF	protection factor
$\overline{PF}$	arithmetic average protection factor
$\overline{PF}_w$	averaged weighted protection factor
PMT	photomultiplier tube
ppm	parts per million
psi	pounds per square inch
R	resistor
RQFT	respirator quantitative fit testing
sin x	sine of x
STANAG	Standardization Agreement (NATO)
STP	standard temperature and pressure
T	talking
TH	turning head side-to-side
TTL	transistor-transistor logic
UD	moving head up-and-down
USA	United States Army
USAFSAM	United States Air Force School of Aerospace Medicine
v or V	voltage
$\overline{V}$	time-averaged voltage
V/F	voltage-to-frequency
Z_{out}	output impedance